

Technological Advisory Committee

Welcome to June 4, 2020 Meeting



Agenda

10:00am - 10:15am	Introduction and Opening Remarks
10:15am - 10:30am	Announcements and Roll Call
10:30am - 11:15am	5G IOT WG
11:15am - 12:00pm	5G RAN Technology WG
12:00pm - 1:00pm	Lunch Break
1:00pm - 1:45pm	Future of Unlicensed Operations WG
1:45pm - 2:30pm	Artificial Intelligence WG
2:30pm - 3:00pm	Closing Remarks
3pm	Adjourned



5G/IoT/O-RAN Working Group 2020

WG Chairs: Russ Gyurek, Cisco & Brian Daly, AT&T

Date: June 4, 2020



Outline for FCC Formal Readout: June 4, 2020

- WG participants
- Charter
- Summary of SMEs and topics YTD
- Standards update
- Spectrum view
- O-RAN Update
- IoT update
- Proposed next focus areas
- Potential areas for recommendations



2020 Working Group Team Members

- Ahmad Armand, T-Mobile
- Mark Bayliss, Visualink
- Marty Cooper, Dyna
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dale Hatfield, Univ of Colorado
- Haseeb Akhtar, Ericsson
- Steve Lanning, Viasat
- Greg Lapin, ARRL
- Lynn Merrill, NTCA
- Robert Miller, inc Networks
- Jack Nasielski, Qualcomm
- Mike Nawrocki, ATIS
- Charlie Zhang, Samsung
- Dennis Roberson, entigenlogic
- Scott Robohn, Juniper
- Jesse Russell, incNetworks
- Travis Russell, Oracle
- Kevin Sparks, Nokia Bell Labs
- Marvin Sirbu, Spec. Gov. Emp.
- Tom Sawanobori, CTIA
- David Young, Verizon
- David Tennenhouse, VMware

FCC Liaisons: Michael Ha, Padma Krishnaswamy, Charles Mathias, Ken Baker, Sean Spivey, Nicholas Oros, Monisha Ghosh



2020 Charter from FCC

5G in low/mid/high frequency bands - critically important to the communications industry, our economy, and U.S. international competitiveness

5G systems are now being deployed, and **6G is being discussed**

- Provide information on the **development and deployment** of this technology, make recommendations, and provide technical insights on new developments that have arisen

Recent industry developments in the **virtualized radio access network (RAN)** space, such as those undertaken by the O-RAN Alliance, have the potential to disrupt conventional cellular network design and deployment

- How scalable are such approaches and what time frames should be anticipated before scalability is achieved?
- How can v-RAN help large and small companies to become more efficient or competitive?
- What are the key challenges of disaggregating the network among multiple vendors?
- How can such disruptive technologies be tested and deployed in realistic environments?
- How will they evolve to keep pace with the ever increasing bandwidth requirements of cellular systems?

Other topics for this Working Group include:

- How can 5G services over mmWave bands be made **more robust**?
- **How will 5G coexist** with Wi-Fi in bands with existing and new unlicensed devices?
- What is the status of the deployment of **service by verticals** such as transportation, energy, health care, etc. and is any Commission action needed to encourage this deployment?
- Is **dedicated or shared spectrum** needed to support industrial IoT applications, what spectrum would be suitable for this purpose, and what are the enabling technologies to consider? Are there any other communication technology trends about which the Commission should be aware to prepare for the future beyond 5G?

5G/IoT/O-RAN: Work Distillation

1

5G

- A. Development & deployment.
New technology drivers, insights and market view
- B. How will 5G co-Exist with unlicensed bands and services?
- C. Future: beyond 5G.
6G progress

2

IoT

- A. What is the status of deployment of 5G by vertical: Transportation, Energy, HC, Industrial, Enterprise, etc.
What can FCC do to accelerate?
- B. What are industry specific needs related to spectrum; licensed, dedicated, shared
- C. What is suitability of spectrum for verticals

3

O-RAN

- A. Tech review related to potential to disrupt conventional cellular network design/deploy.
- B. How scalable is O-RAN, time-frame (RAN WG?)
- C. How will O-RAN help drive efficiency, competitiveness of RAN companies?
- D. What are challenges in disaggregating/multi-vendor approach
- E. Testing and deployment
- F. O-RAN evolution

5G/IoT/O-RAN Work Plan and Activity Summary



- **O-RAN**

- O-RAN Framing
 - Collaborate with the RAN WG
 - O-RAN alliance review
 - 3GPP related work review
- Adoption, market impact/timing
- WW competitiveness
- Key challenges
- *Provide recommendations*

- **5G Development and deployment**

- Advise the FCC on standards progress, impacting events

- **Technology awareness: beyond 5G**

- Emerging technologies
- 6G planning updates
- Non-terrestrial networks (Satellite +), Wi-Fi6
- ITU network 2030 work

- **5G verticals and related impacts & needs**

- Industrial, Health-care, transportation, energy/critical infrastructure

- **Spectrum related to verticals**

- Vertical specific requirements
- Emerging spectrum policies (WW)
- Shared spectrum opportunity and assessment (CBRS, NTIA, DoD)
- USA Competitive impacts
- *Provide recommendations*

- **5G impact related to unlicensed bands and services**

- Interference
- Co-existence
- *Provide recommendations*



SME Speakers and Key Insights

Organization	Topic	Speaker	Summary
	O-RAN Alliance Overview and Status	Jack Murray	<ul style="list-style-type: none"> O-RAN Alliance is having success on opening the RAN architecture Working with the second version of Open Source SW- <i>Bronze</i> Focused on a option 7.2 split
	6G and the Marketplace of the future	Mike Nawrocki	<ul style="list-style-type: none"> ATIS has created a 5-10 year view on evolution of the LTE marketplace Key evolution: Cloudification, Privacy/Trust, Personalization, Intelligent Connectivity and Enablement of new business models and adjoining industries
	Shared Spectrum: CBRS Alliance	Preston Marshall	<ul style="list-style-type: none"> CBRS SAS systems are in operation, 5 commercial SAS vendors A data driven model could provide a greater number of licenses Future sharing should focus on more than just geographic separation
	IIoT- Factory Wireless Requirements	Paul Didier	<ul style="list-style-type: none"> Industrial has multi-level latency needs: <1msec to 250msec. The majority (~95%) of uses don't need the tightest TSN (IEEE) requirements For very tight control loops, even the best wireless wont meet needs <1ms
	RAN tech talk: A joint WG session	Rob Soni	<ul style="list-style-type: none"> vRAN architectures have multiple configurations on CU/DU distances and functions across the network architecture Virtualization provides a very flexible deployment strategy for SPs

Speakers: Key Insights pg.2

Organization	Topic	Speaker	Summary
	O-RAN Alliance Deep Technical Review	Sachin Katti (Stanford, O-RAN, Vmware)	<ul style="list-style-type: none"> RAN programmability through near-RT & non-RT RICs- this has high value O-RAN has opened up the RAN network: includes radiohead, cloud and virtualized functions. Limited pre-commercial tier 1 deployments (option 7-2x)
	5G for Factory Wireless	Andreas Mueller	<ul style="list-style-type: none"> 5G is the central nervous system of the factory of the future IIoT must have private spectrum: control, security, economic requirements 5G- ACIA is defining Industrial requirements and participating in 3GPP
	O-RAN Deployments in the Wild	John Baker	<ul style="list-style-type: none"> O-RAN has expedited RAN virtualization Significant TCO savings (31%-49%) due to OpenRAN & O-RAN features O-RAN has opened up Open Fronthaul 7-2x split
	Precise Timing and Location: GPS Evolution	Ganesh Pattibiraman	<ul style="list-style-type: none"> While GPS outages have increased, GPS is not going away Jamming is a significant issue Other technologies combined with GPS provide greater resilience/reliability
	Spectrum overview	Kumar Balachandran	<ul style="list-style-type: none"> US has a lack of mid-Band spectrum compared to WW allocations Spectrum diversity is very important to successful 5G deployment Industry applications need spectrum to be predictable over the long-run
	O-RAN	Per Emanuelsson	<ul style="list-style-type: none"> O-RAN provides opportunities but creates complexity with disaggregation Ericsson as a vendor is very positive to RAN optimization and A1, O1 interface O-RAN has challenges related to security and integration costs



Standards updates



Standards Update



- Standards impact from **Coronavirus**
- 3GPP, ATIS, IETF, etc. face to face meeting cancellations now *at least* through December
 - 3GPP Project Coordination Group (PCG) approved a new Annex to the 3GPP Working Procedures, to cover “Special procedures for exceptional situations restricting travel”, to allow 3GPP to function w/ virtual meetings
 - describes how e-meetings can hold votes and how the vote will be conducted
 - process to allow the leadership to hold physical meetings – (8 weeks notice) - when the situation allows
 - but ... any resumption of the F2F meeting cycle is not just dependent on the virus being defeated; will take time for Government and company travel restrictions to be lifted
- e-meetings have generally gone very well
- All regional and global standards and industry associations affected
 - 5GAA, 5G ACIA, IETF, IEEE
 - ATIS committees hold many virtual meetings so more “business as usual”



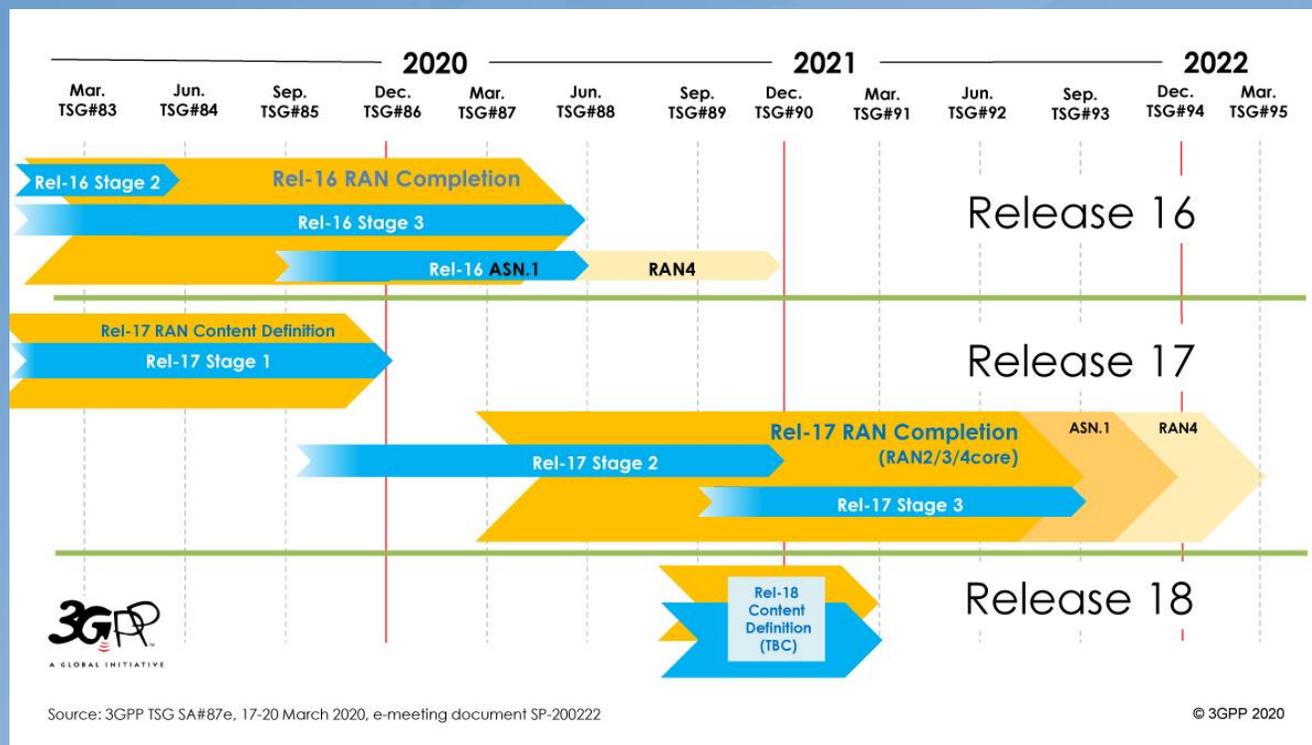
Standards Update – Release 16

3GPP Release 16

- The 5G System – Phase 2
- V2x Phase 3: Platooning, extended sensors, automated driving, remote driving
- Industrial IoT
- Ultra-Reliable and Low Latency Communication (URLLC) enhancements
- NR-based access to unlicensed spectrum
- 5G Efficiency: Interference Mitigation, SON, eMIMO, Location and positioning, Power Consumption, eDual Connectivity, Device capabilities exchange, Mobility enhancements
- Enhancements for Common API Framework for 3GPP Northbound APIs (eCAPIF)
- FRMCS Phase 2

Release 16

Was targeted to be complete in March, appears to be on track for both Stage 3 and ASN.1 in following the “June” 3GPP virtual plenary meetings



Standards Update – Release 17

For Release 17, the work package is stable and SA2 has prioritized the stage 2 work, with feature studies started in Q2 2020

SA content highlights in Rel-17

include:

Enhancements

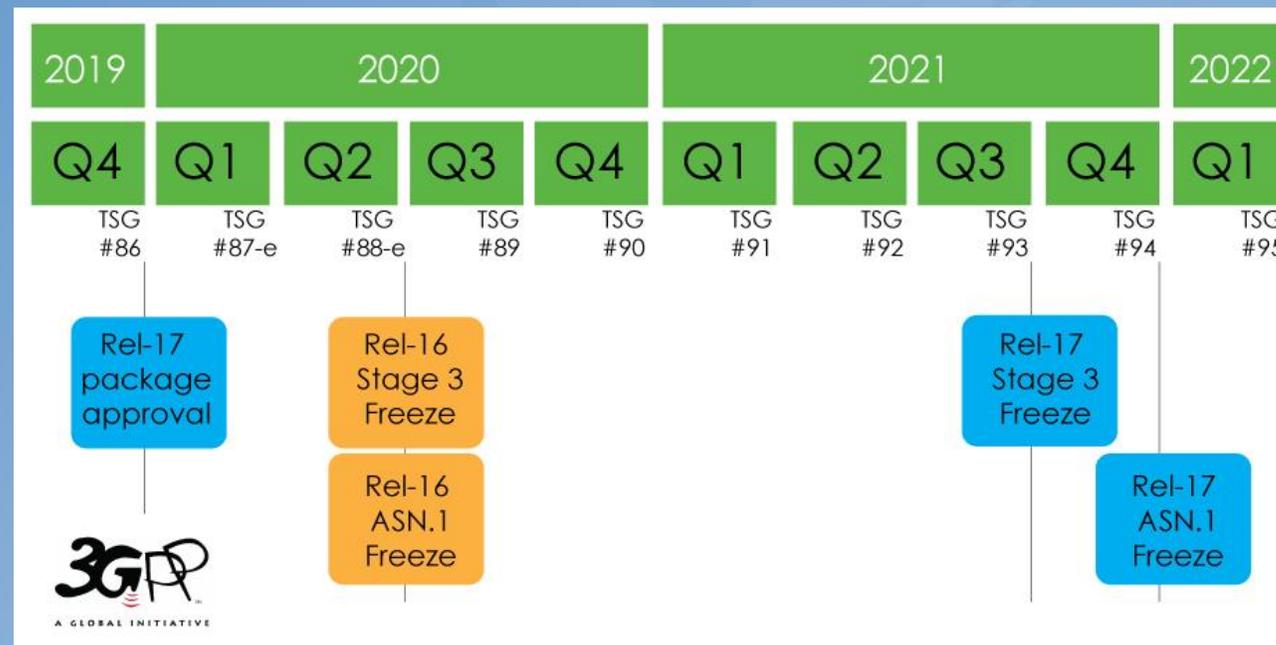
- Slicing (3rd phase), EDGE computing
- Network automation & Orchestration
- NB-IoT enhancements
- Location services
- Drones

New features

- 5G proximity services
- 5G multi-cast and broadcast
- Satellite integration
- Industrial IoT
- 5G media and VR

TSG SA - Rel-17 progress:

- Architecture :- WG SA2 has approved Rel-17 study items for work during Q2, 2020
- API related :- WG SA6 has made good progress on Rel-17. Take a look at future railways work and enhancements for Mission Critical



Standards Update – Approved Rel. 18 Studies

- Enhanced Access to Network Slice (EANS)
- Off Network for Rail
- 5G Timing Resiliency
- 5G Smart Energy Infrastructure
- Ranging Based Services
- Enhancement to Residential 5G
- Personal IoT Network
- ~~Network as a Service (NaaS)~~
- ~~Vehicle Mounted Relays~~
- ~~Enhanced Synch as a Service (eSaaS)~~
- ~~Enhancing Satellite Access in 5G~~
- ~~Service Oriented Robots w Human Interactions~~
- ~~Blockchain as a Service (BaaS)~~
- ~~Holographic Type Communication~~
- ~~Enhancement for Multi Media Services in 5G~~
- ~~Smart Logistics Mgmt (SLIM)~~
- ~~5G Tactile Internet (TI)~~
- ~~5G Utility Communication~~
- ~~Junction Chaining in 5G System~~

Release 18:
the work
package is
aggressively
being reduced



5G Spectrum



North American Traffic growth out-paces every other regions WW

160EB

Total traffic predicted to reach 160 exabytes per month in 2025

North America

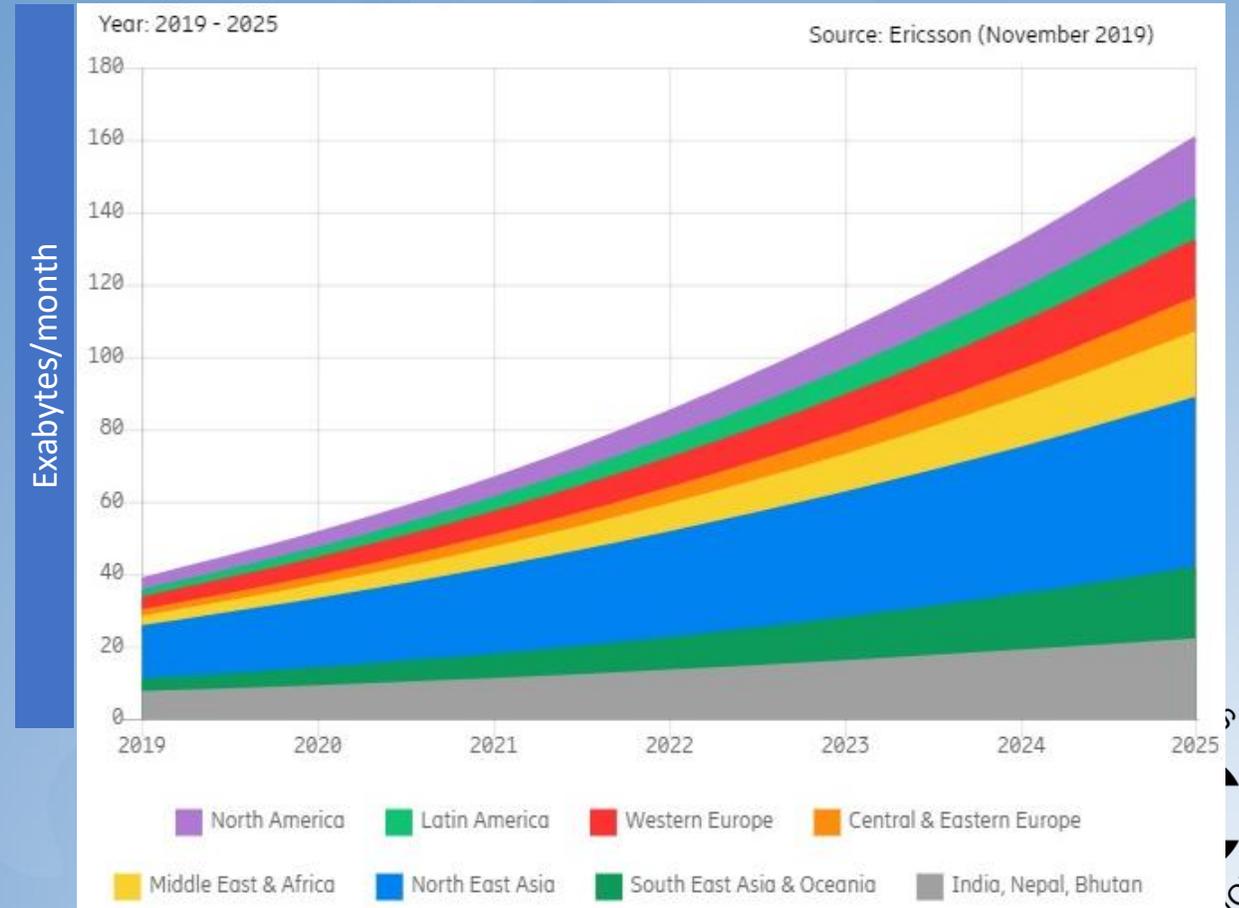
Total North American traffic exponentially increasing;

Increasing from 8.3-10.5% share of global traffic between 2019-2025;

Global traffic expected to double every 3 years

17 EB

Total North American traffic predicted to reach 17 exabytes per month in 2025



US Licensed Mid- and High-Band Spectrum

Mid-band				
WCS	BRS/EBS	CBRS ¹	C-Band	Total
2.3 GHz	2.5 GHz	3.5 GHz	3.7-4.0 GHz	564 MHz licensed dedicated spectrum* (664 with CBRS GAA)
20 MHz	194 MHz	150 MHz(max)	280 MHz (min)	
Paired	Unpaired	Unpaired	Unpaired	

* CBRS PAL spectrum auctions are in July 2020 and included in total; anticipated quality is closer to commercial mobile spectrum

¹ CBRS Spectrum is shared on a secondary basis

High-Band					
Sub-mmW		mmW			
24 GHz	28 GHz	37 GHz	39 GHz	47 GHz	Total
700 MHz	850 MHz	1000 MHz	1400 MHz	1000 MHz	4950 MHz
Unpaired	Unpaired	Unpaired	Unpaired	Unpaired	

Low-Band (sub 1 GHz): **208MHz**

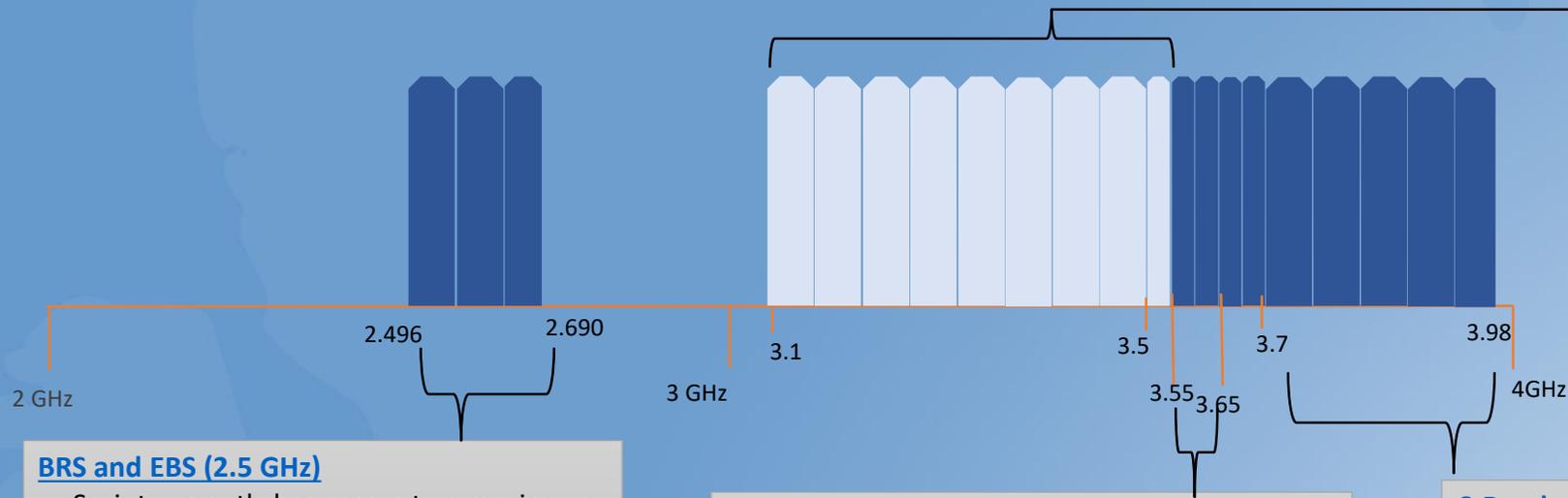
Additional Mid-Band (1-2Ghz): **265MHz**

Total: **573MHz**



Total low-band and mid-band allocation in the US amounts to 1237 MHz (Including full CBRS spectrum)

Opportunity for Mid-band Spectrum is in 3.1 – 3.55 GHz Bands



Opportunity lies in repurposing 450 MHz in the NTIA Bands with priority access to incumbents

- 3.1 – 3.5 GHz:** Navy Air and Search Radar
- 3.3 – 3.6 GHz:** Air Force AWAC aircraft & surveillance
- 3.5 – 3.65 GHz:** Navy Air Traffic Control Radar
- 3.11 – 3.49 GHz:** Army Radiolocation Radar
- 3.1 – 3.6 GHz:** Air Force Station keeping
- 2 – 4 GHz:** Marine Corp (exact frequency classified)

BRS and EBS (2.5 GHz)

- Sprint currently has access to a maximum of 194 MHz and avg. of 148.1 MHz of the spectrum nationwide
- Portions of the EBS whitespaces will be auctioned in 2021

CBRS PAL

10 channels of 10 MHz each between 3.55 – 3.65 GHz; not more than 70 MHz to be made available in each county (limitation of up to 40 MHz aggregation per operator)

Tiered access as follows:

- **Tier 1:** Incumbents
- **Tier 2:** PAL holders; get access only if incumbents not present
- **Tier 3:** GAA; get access if no incumbents or PAL holders present

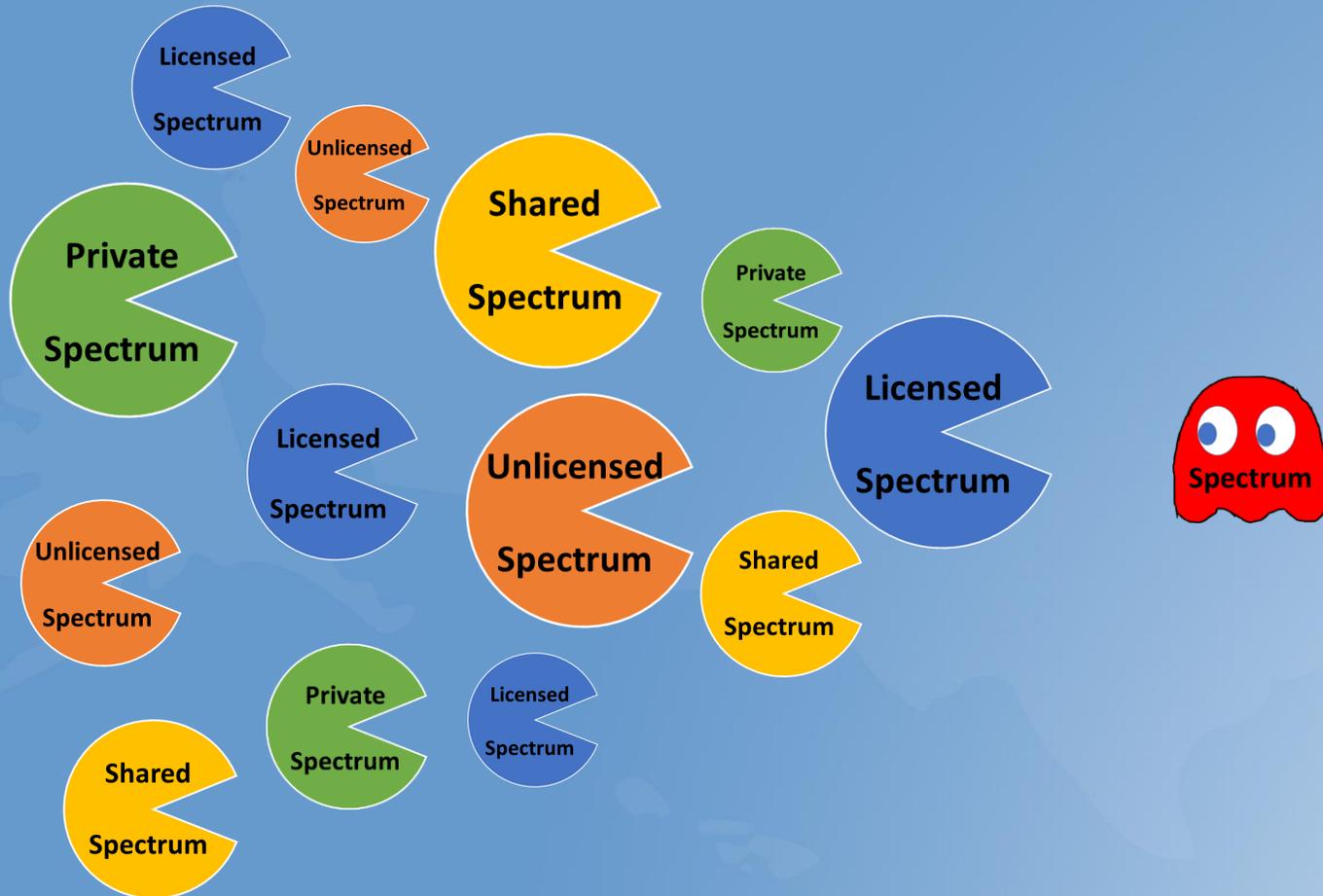
C-Band

14 channels of 20 MHz each between 3.7 – 3.98 GHz to be auctioned:

- Channel A:** 3.7 – 3.8 GHz; 5 blocks of 20 MHz each
- Channel B:** 3.8 – 3.9 GHz; 5 blocks of 20 MHz each
- Channel C:** 3.9 – 3.98 GHz; 4 blocks of 20 MHz each



Spectrum Diversity Challenge



Spectrum Allocation Challenge

- Spectrum Diversity is important
- All users want additional allocations and/or more spectrum
- Mid-band is the sweet spot for most applications (reach & bandwidth)
- However, mid-band has limited availability (incumbents)
- FCC National Spectrum Management: *What is best use of spectrum and promotes fair, economically efficient and effective management policies while avoiding harmful interference**
- How to create a future focused plan

*<https://www.fcc.gov/general/best-practices-national-spectrum-management>

5G Key Ingredients of Success

5G Radio Graphic Equalizer



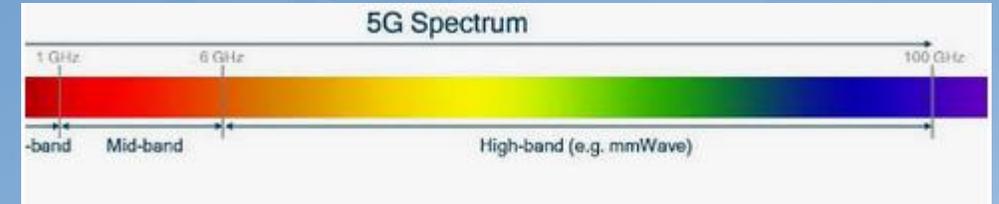
There are trade-offs within each of the 3 critical factors:

- Adding spectrum is limited and challenging based on availability
- Densification helps get more out of existing spectrum, but costly
- Spectral efficiency helps in use and licenses, however, difficult technically

A balance of all three are necessary to meet the various market demands

Spectrum: Next Areas of Focus

- Explore shared options
- Mid-band is a priority for SP use
- Monitor success of CBRS PAL starting July 2020
- Deep dive on IoT verticals and related requirements tied to potential spectrum needs
 - Explore spectrum that has high re-use value (mmWave)
- Explore new and emerging technologies that can drive spectrum use efficiencies
- Future view: what will 6G need? Wi-Fi7?
- Consider full network architectures: from UE to core
- Applications requirements tied to spectrum needs, per band
- Data driven approaches to licenses in shared environments



Open RAN, O-RAN, and vRAN



RAN Definitions: Open RAN, O-RAN, and vRAN

OpenRAN - disaggregated RAN functionality built using open interface specifications between elements. Can be implemented in vendor-neutral hardware and software-defined technology based on open interfaces and community-developed standards.

O-RAN – refers to the O-RAN Alliance or designated specification. O-RAN Alliance is a specification group defining next generation RAN infrastructures, empowered by principles of intelligence and openness.

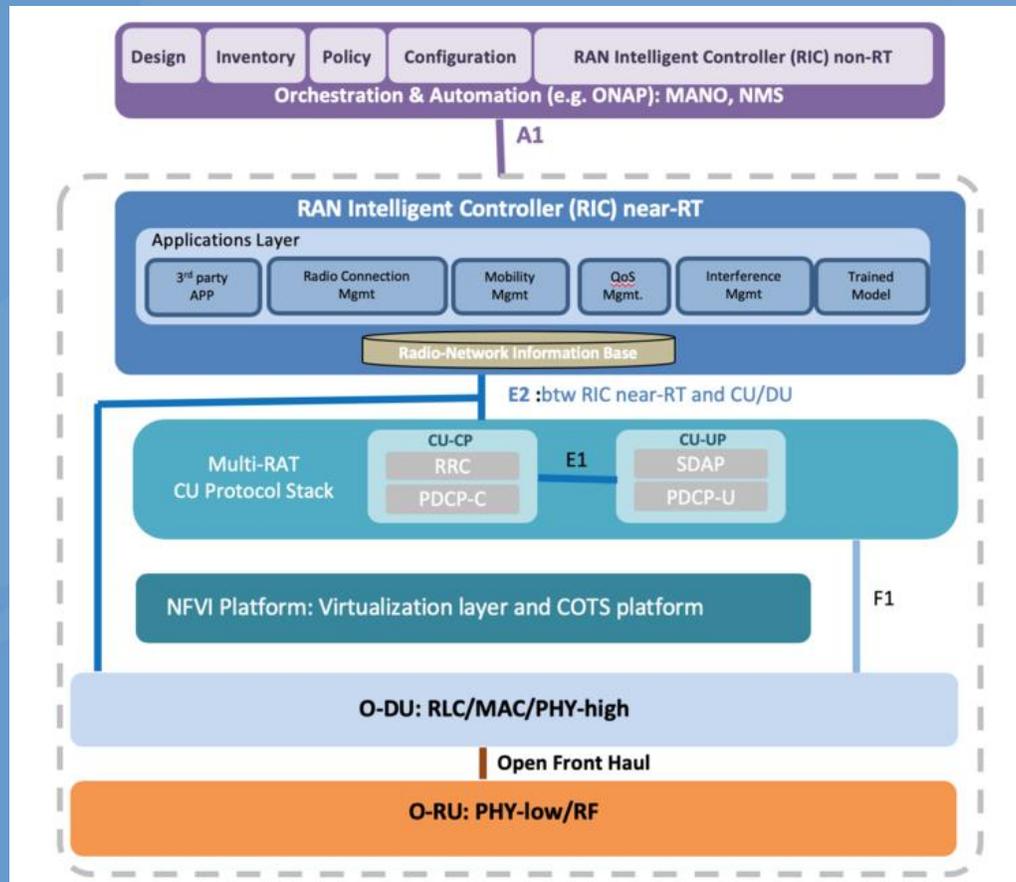


vRAN – an implementation of the RAN in a more open and flexible architecture which virtualizes network functions in software platforms based on general purpose processors.

vRAN utilizing open interfaces is one component of OpenRAN



O-RAN Alliance High Level Architecture



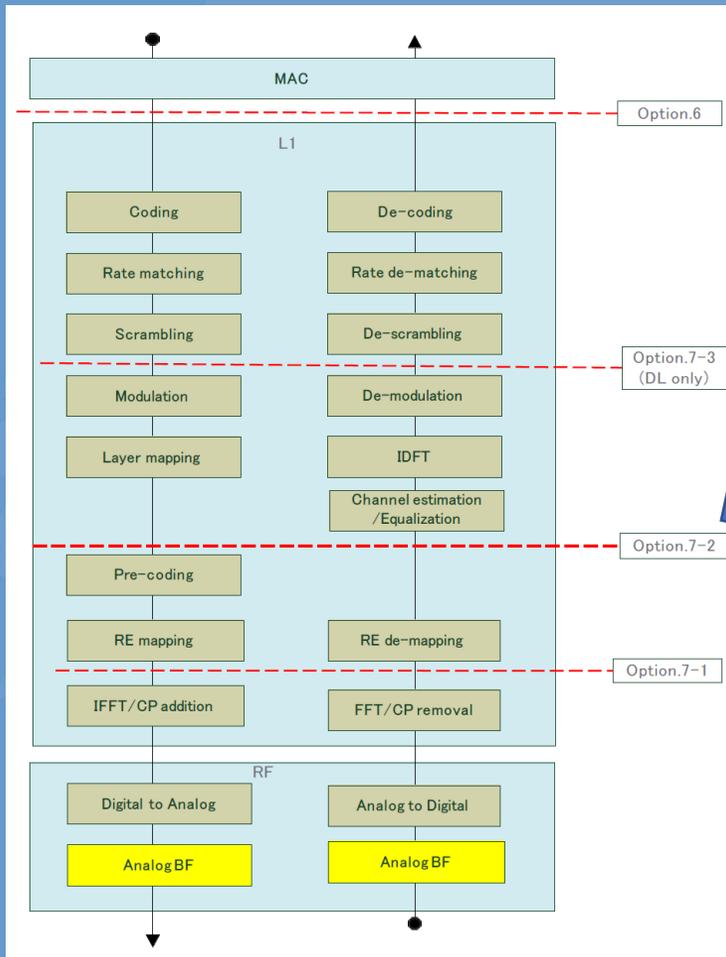
Source: O-RAN Alliance

Based on well-defined, standardized interfaces to enable an open, interoperable supply chain ecosystem in full support of and complimentary to standards by 3GPP and other industry standards organizations

Uses COTS HW and virtualization SW that enables abstraction – in the form of VMs or containers – to provide multiple hierarchal cloud deployment options



O-RAN 7-2x Architecture

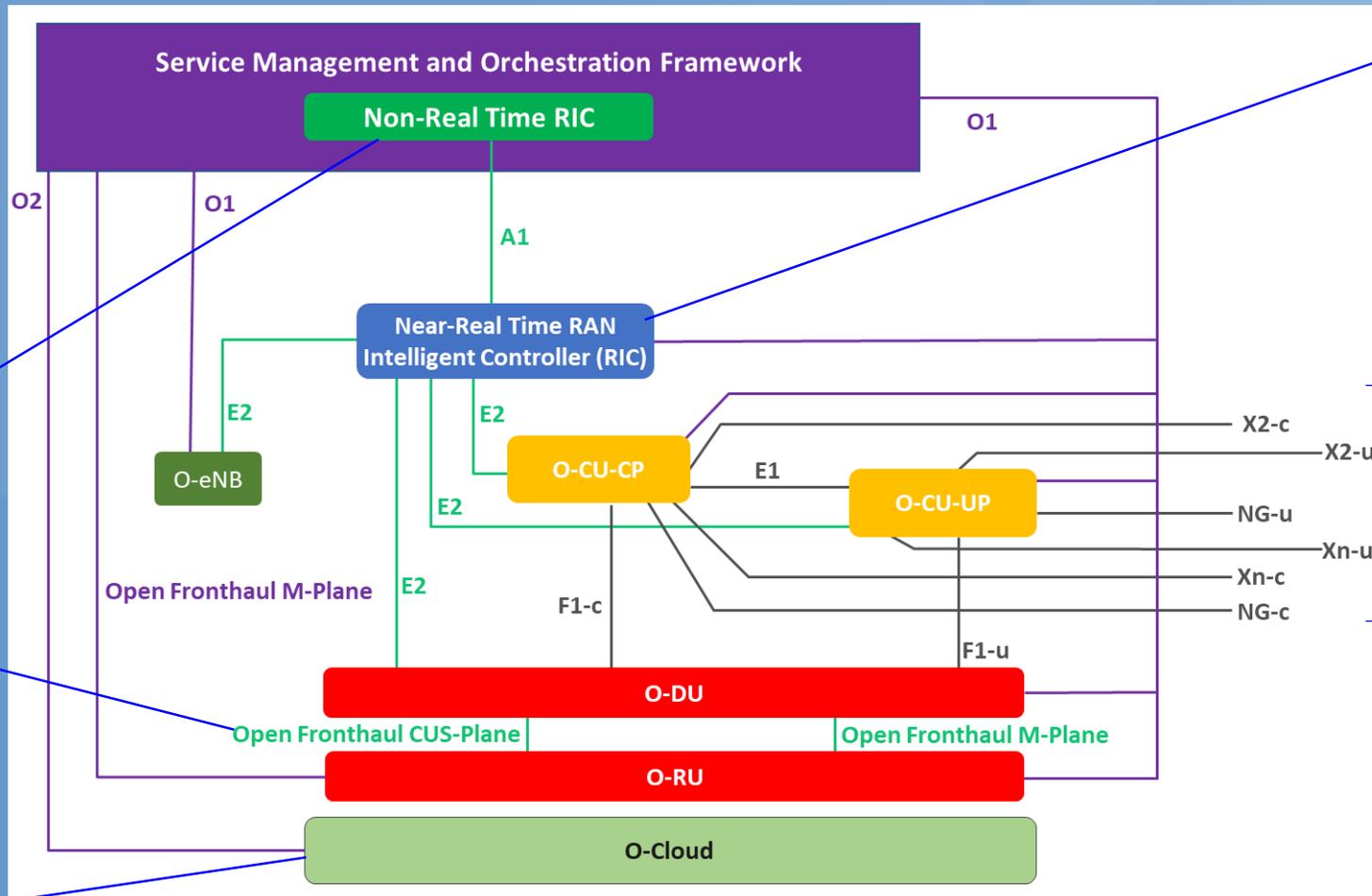


O-RAN selected split Option 7-2x

- Widely applicable split, does not rule out other splits
- Trade-off between O-RU complexity and the interface throughput:
 - O-RU Cat A, without precoding (low-complexity)
 - O-RU Cat B, with precoding
- On-going WI: Shared cell, conformance test specs, FH interface, cooperative transport interface (CTI)
- Emerging RU vendor ecosystem with pre-commercial deployments by a Tier-1 announced

<https://www.o-ran.org/specifications>

O-RAN Logical Architecture



Intelligent RAN optimization in non-real-time (>1 sec):

- Policy-based guidance using data analytics and AI/ML
- Data collection and provisioning services of O-RAN nodes

Control and optimization of RAN resources in near-real-time (10 ms – 1 sec):

- xApps to collect near real time RAN data using E2 interface
- Guided by policies and enrichment data from A1 interface

3GPP interface profiles (E1, F1, X2 and Xn) for supporting brownfield deployment

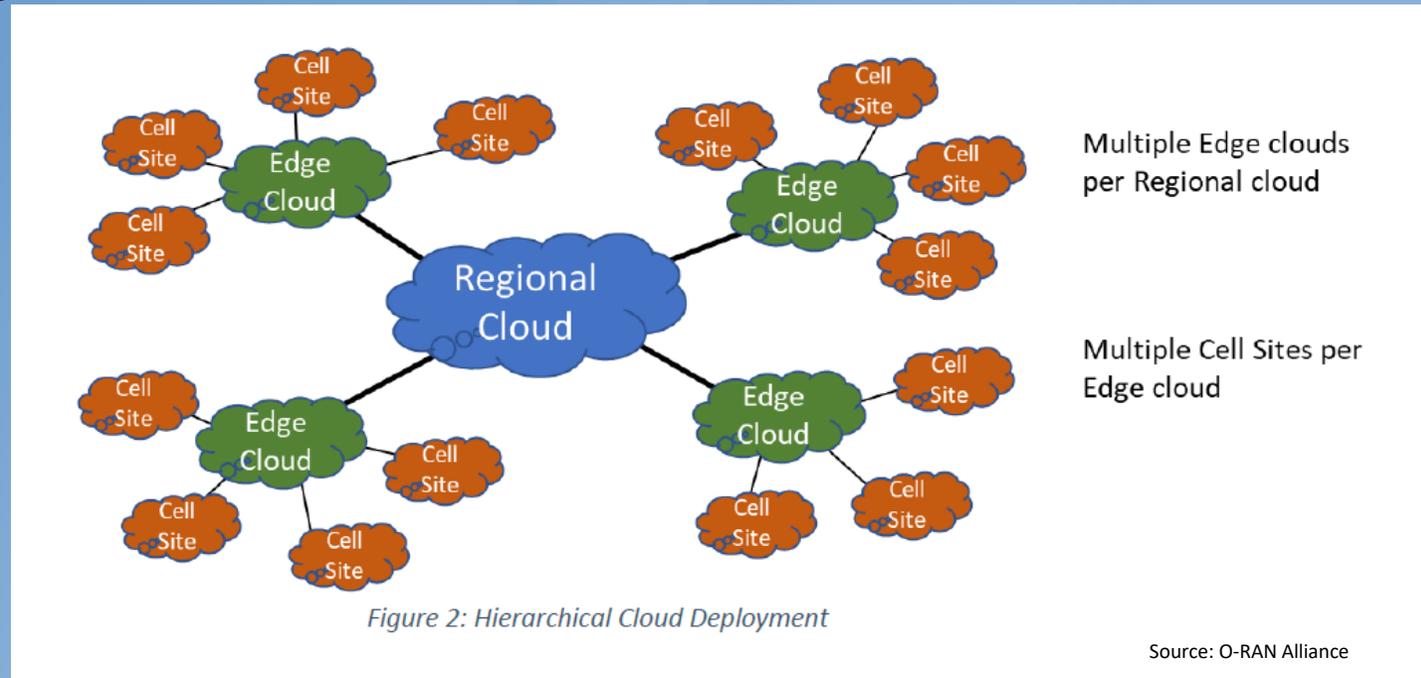
Lower Layer Split (LLS) Option 7-2x

COTS hardware based RAN virtualization platform



Open RAN/O-RAN Observations

- 22 MNOs have announced intentions to deploy Open RAN based commercial networks globally (as of May 31, 2020)
- Operators, integrators and analysts indicate cost savings of 35-49% as the main driver
 - Open RAN/O-RAN is capable of reducing network CAPEX and OPEX
 - Open source SW and HW reference designs
 - Native cloud
 - Embedded intelligence
- Improved network efficiency and performance
 - Automation – continual monitoring and real-time close-loop control



Open RAN Policy Coalition- *New!*

- Advocate for government policies supporting the development and adoption of open and interoperable solutions in the RAN
- Open interfaces will help ensure interoperability across different players in the ecosystem and lower the barrier to entry for new innovators
- “Opening” protocols and interfaces between the various subcomponents (radios, hardware and SW) in the RAN, move to an environment where networks can be deployed with a more modular design, without being dependent upon a single vendor
- 32 global technology companies as members

Goals: Promote policies that:

- Support global development of open and interoperable wireless technologies
- Signal government support for open and interoperable solutions
- Use government procurement to support vendor diversity
- Fund research and development
- Remove barriers to 5G deployment
- Avoid heavy-handed or prescriptive solutions



O-RAN Observations

- Value propositions:
 - Reduce capital and operating costs
 - Common vendor implementation across 'open' interfaces and eco system
 - Add RAN Programmability through open APIs (Non-RT and Near-RT RICs)
 - Increase deployment velocity and flexibility by enabling RAN virtualization (decouple hardware and software)
 - Pivot RAN to software based environment
 - Leverage open source software
- Challenges:
 - Business case for 'opening' the RAN while maintaining the KPIs
 - Opening and disaggregating radio communications are very complex
 - Integration and life cycle management of components (software/hardware) from multiple vendors
 - Open source software is not deployable out of the box
 - Security aspects of disaggregated architecture (a Security Task Group has recently been launched)



IoT: Requirements



IoT Observations

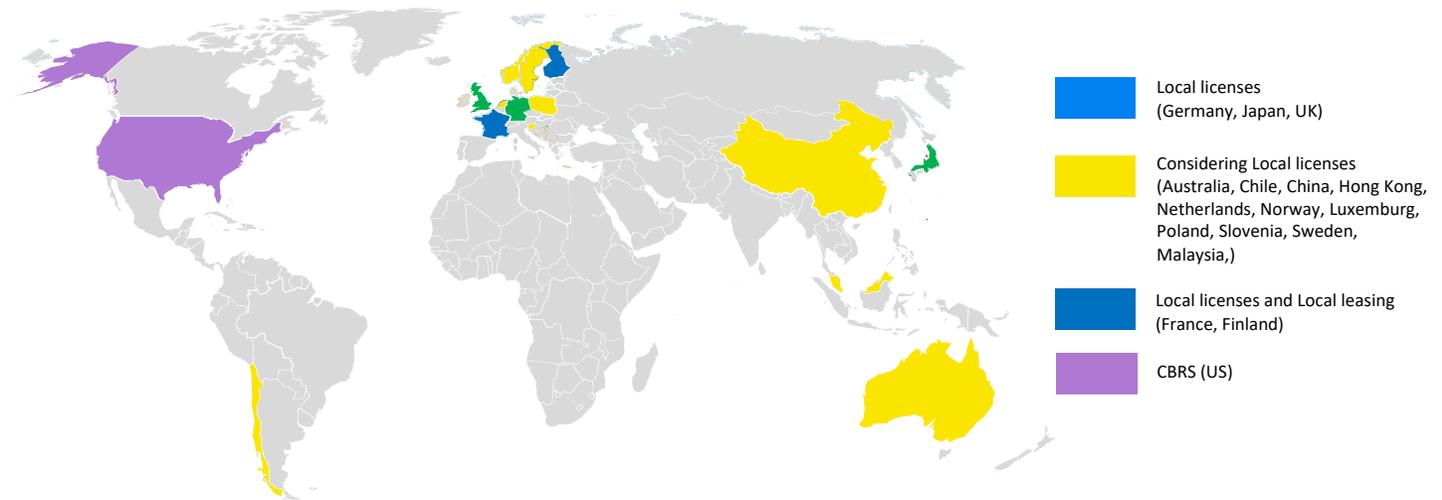
- Vertical view
 - Industrial: Industrial control systems and automation require very tight latency, security and on-prem compute. General view of industrial industry that IIoT needs private spectrum (as presented by Industrial leader and ACIA founder). OT/IT control desired to support security, interruptions, and investment protection
 - Healthcare, transportation, cities, enterprise to be added
- Spectrum view
 - Shared spectrum provides some opportunities for a enterprise and industrial use
 - Concerns on interruption as a “stand-alone” network service (incumbents and PAL priorities)
 - WW Industrial leading countries are moving forward with “private/Locally Licensed Spectrum options
 - What is best spectrum for private uses: in-building or campus? WW initial deployments in mid-band but second wave of mmWave
 - mmWave provides high bandwidth with great re-use characteristics
- WW Developments- see map



WW Spectrum Actions - Private

- Spectrum allocations for “private use emerging
- A few countries have adopted property/real-estate based licenses for local services
- Initial spectrum availability is in mid-band
- Germany is furthest along: licenses granted
- Industrial has been a top applicant
- In general the responsibility to comply with regulations is with the licensee

Spectrum for Industries, April 2020



The map does not separate between

- Mid band and high band (some countries has different principles in different bands)
- Different options in different bands in one country (same country in more than one list)

6G Update



6G Update

- *ATIS: Promoting U.S. Leadership on the Path to 6G Technologies*
- Core 6G Technologies:
 - AI-Enabled Advanced Networks and Services
 - Advanced Antennas and Radio Systems
 - Multi-Access Network Services
 - Healthcare
 - Agriculture
- National plan for technological excellence:
 - Make available additional R&D funding focused on a core set of technological breakthrough areas where the U.S. can lead.
 - Expand R&D tax credits to encourage massive investment in a core set of technologies that will promote U.S. leadership.
 - Work with industry to develop a consumer- and business-centric solution to wireless spectrum challenges by creating a national spectrum policy.
 - Explore innovative ways to promote widespread commercial adoption of U.S. developed and produced hardware and software through financial incentives to public and private sectors.

Viewpoint: It is Time to Engage



5G/IoT/O-RAN Proposed Next Steps

- Mid-band spectrum (licensed) – prioritization
- IoT: potential for mmWave spectrum use (WW uses emerging)
- 6G: spectrum planning should start now
- Spectrum use efficiency- FCC to call for industry focus (devices and equipment)
- O-RAN: Explore split options and vertical needs
- O-RAN: Evaluate the change in completion related to deployments
- Security: Jamming and spoofing (shared to licensed)
- Deeper view on location and timing tied to 5G
- Neutral host work tied to O-RAN support
- Co-existence between licensed and unlicensed
- Traffic offloading: is there a difference between 4G and 5G
- 5G resiliency



Moving toward *Actionable* Recommendations



Potential Areas for Recommendation

- Licensed mid-band spectrum
- Locally Licensed Spectrum (LLS) for IoT vertical (private use)
- O-RAN support related to promotion of adoption and deployments
- Efficiency on spectrum use
- Security: related to spectrum jamming
- 6G: spectrum planning and viewpoint
- Shared spectrum: regulatory signal strength limits potentially reduce the efficiency of CBRS; data driven model limits could provide greater optimization



Thank You!



Supporting Material



Snapshot of Open RAN Deployments

- Rakuten has deployed a commercial fully cloud-native mobile network with open vRAN in Japan, with radios from multiple vendors both in 4G and 5G.
- AltioStar has deployed its software with 4G/5G radios from Airspan, MTI, Nokia and Sercomm and is working with radios from Flex, Fujitsu, KMW, NEC and Xilinx to deploy by mid-year.
- On April 29, 2020, it was announced that India's largest integrated telecommunications services provider, Bharti Airtel, had deployed AltioStar's open vRAN solution across multiple major cities in India.
- Mavenir has deployed with Vodafone Idea and is partnering with Dish to deploy a fully virtualized nationwide network with Open RAN.
- NTT DOCOMO has already realized interoperability between base station equipment of Fujitsu, NEC and Nokia with O-RAN compliant fronthaul and X2 interfaces in their 5G commercial service.
- Telefónica has established an Open RAN consortium of hardware and software companies aimed for the development and deployment of open RAN in 4G and 5G, comprising the necessary design, development, integration, operation and testing activities required to materialize Open RAN.
- Parallel Wireless has been deploying Open RAN since 2015 with Vodafone, Telefonica, MTN, Optus, and is a strategic partner for rural U.S. operators and members of the Competitive Carriers Association (CCA). Source: Open RAN Policy Coalition



Snapshot of Open RAN Trials

- AT&T is one of the founding members and currently chairs the O-RAN Alliance. AT&T has also conducted several demos and trials including working with CommScope and Intel to demonstrate a mmWave 5G gNB and open front haul leveraging developments at O-RAN.
- Verizon is actively working with its current suppliers and smaller software developers to advance the open interface model.
- Vodafone is currently chair of TIP and has active trials of Open RAN ongoing in Turkey, Mozambique, DRC, Ireland and UK with Parallel Wireless and Mavenir.
- AT&T recently hosted the O-RAN Alliance Plugfest in New York City, where Samsung demonstrated the multi-vendor compatible Configuration, Performance, and Fault Management capabilities of the O1 interface.
- Telefónica conducted in 2019 successful open RAN trials in Brazil based on 4G, which are being evolved in 2020 to more ambitious 4G/5G trials that position ourselves towards 4G/5G commercial deployments.
- VMware, Inc. and Deutsche Telekom recently announced the companies are collaborating on an open and intelligent virtual RAN (vRAN) platform, based on O-RAN standards, to bring agility to radio access networks (RANs) for both existing LTE and future 5G networks.



5G RAN Technology Working Group Readout to the TAC

WG Chairs: Tom Sawanobori, CTIA & Kevin Sparks, Nokia

Date: June 4 2020

Meeting: TAC virtual meeting



Outline

- Charter
- Working Group Members
- Summary of presenters
- Updated status of workplan
- Overview of RAN components & definitions diagram
- Key insights (so far) – per domain (RF, vRAN, Interference Mgmt.)
- ‘Heat map’ of high impact topics
- Plans/focus of next ‘semester’

5G RAN Technology WG: 2020 Charter

Broad Areas:

UE - RF - Fronthaul - vRAN/BBU → Spectrum Mgmt./Interference

Explore advanced technologies that may be used in 5G/6G radios, both at base stations and client devices.

1. What is the roadmap of RAN architecture evolution in 5G/6G radios and how does it compare to the previous generations?
2. How does the potentially disruptive network virtualization proposed by O-RAN affect the development of RF front-end and fronthaul technologies?
3. What are the broader implications of the convergence of the use of advanced RF/RAN system components and spectrum management policies?
 - RF front end: advanced multi-band antennas, filtering technology, feed networks, amplifier efficiency, A/D converters, etc.
 - Baseband Processing: vRAN technology & architectures
 - RAN systems: self-optimization & configurability of advanced components, fronthaul technologies, eMBB/URLLC/mMTC performance optimization
4. Does incorporation of these advanced technologies and capabilities into radio equipment warrant a reexamination by the Commission of its policies and procedures pertaining to spectrum management?
5. How can the Commission best characterize the use of advanced RF system components in the analysis of in-band and out-of-band emissions to optimize efficient use of spectrum?
6. How can propagation modeling tools be better utilized to predict interference between systems?
7. How might equipment authorization procedures need to be modified to better address these advanced features, especially as the worst-case configuration used during testing continues to deviate from expected performance under normal operations?
8. What is the potential for interference risks as more dynamic components and features are introduced into advanced wireless systems, which could result in widely varying interference potential over time, particularly across broad geographic areas.

2020 5G RAN Technology Working Group Team Members

- Shahid Ahmed, Imagine Wireless
- Ahmad Armand*, T-Mobile
- Kumar Balachandran*, Ericsson
- Mark Bayliss, Visualink
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- Michael Ha, FCC
- Monisha Ghosh, FCC

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FCC Liaisons: Bahman Badipour, Reza Biazaran, Bob Pavlak, Ken Baker,
Kamran Etemad, Sean Yun, Sean Spivey, Charles Mathias

Speakers and Key Observations

Topic	Speaker		Key Observations
E2E RAN components & flexibility overview	Greg Wright		End-to-end 5G RAN component architecture Flexibility feasibility varies – radio unit (i.e. SDR) not practical, distributed unit (vDU) challenging, and centralized unit (vCU) straightforward
vRAN technology evolution	Rob Soni		V-RAN closely related to edge cloud and O-RAN Cloud scaling and feature velocity bigger driver than TCO savings Multiple types of vRAN w/varying pros & cons
RF: A/D converters	 Boris Murmann		Filtering essential to reducing dynamic range for converters Improving performance, but must consider power consumption Further ADC technology scaling brings mainly density
vRAN technology evolution	Udayan Mukherjee		Progress being made on real-time optimizations for vRAN System integrator is key consideration vRAN/O-RAN in greenfield claim ~30% TCO savings (Rakuten)
5G/UE technology evolution	John Smee		Proliferation of bands for 5G – in addition 4G, other technologies Subsystem modularity is key to manage more bands and interference
mMIMO (especially EIRP/interference aspects)	Moray Rumney		Massive MIMO – beam steering and beam forming provide different benefits across low/mid/high bands Challenges measuring interference and Total Radiated Power

Initial Information Collection & Analysis (plan of attack, progress)



Performance/ Capability	2	1	2	1	Upfront info collection sessions	2
Configurability/ Dynamics	2	1	2	1		2
Implications/ Impacts	3	3	3	3	Downstream discussion/analysis	3
Interference Risks	3	3	-	3		3
	Client (UE)	RF Front End	Fronthaul	Baseband Processing	E2E RAN System	



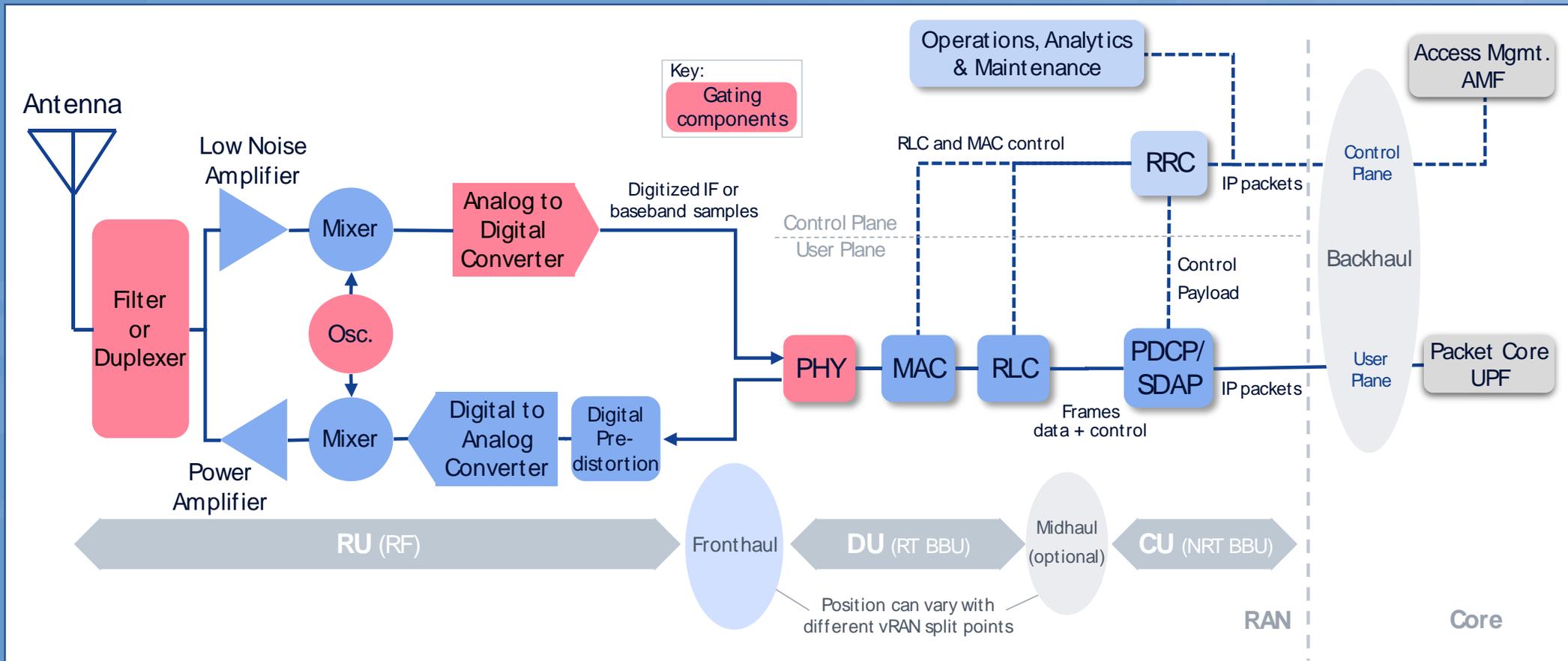
Numbers = rough ordering/priority
Small font = expected lesser effort

Educational outputs: Summary of above

Actionable analysis: Interference, Spectrum Management & Equipment Authorization

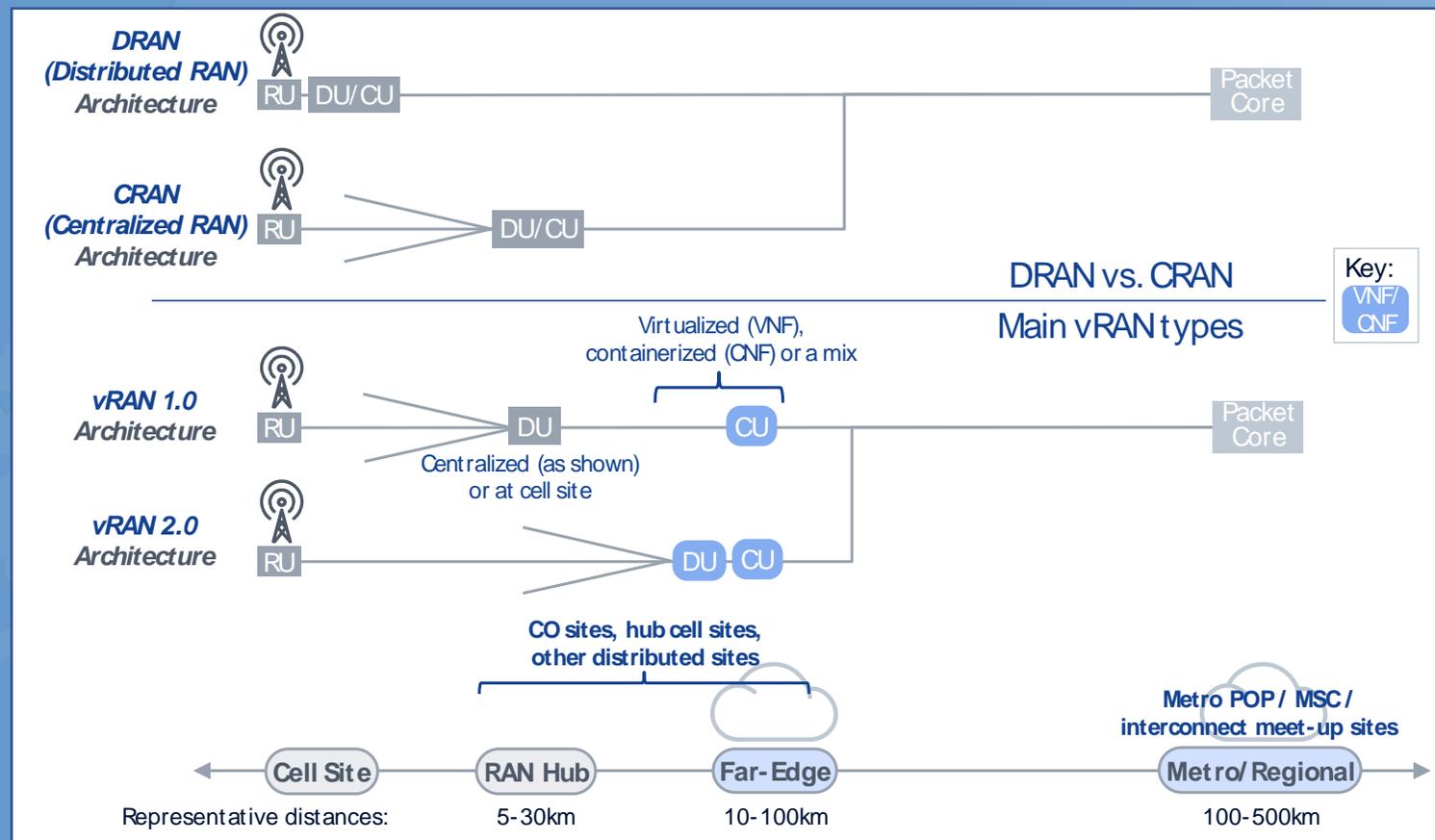


End-to-End RAN Component Architecture



Source: Greg Wright, Nokia Bell Labs

RAN architecture definitions



Clarifying CRAN and vRAN terms

- DRAN vs. CRAN refers to location of baseband processing functions
- Can be classical or virtualized
- Classical DRAN & CRAN architectures deployed widely today

Multiple variations of 'vRAN'

- vRAN 1.0 virtualizes the CU functions
- vRAN 2.0 virtualizes both CU and DU
- vDU variations depending on hardware acceleration (FPGA, SoC, GPU)



Key Insights – RF Overall

- Base station RF chain extremely optimized
 - Closely-coupled tradeoff of throughput/link performance, power, volume, interference mgmt. and cost
- Receive chain more challenging/limiting than transmit
- The most critical components are filters, A/D Convertors, and Oscillators (see next slide)
- Current advances more oriented to handling higher bandwidth
- Prognosis on RF flexibility: SDR-type tunability is not yet on the horizon

Key Insights – RF Critical Components

Filter/Duplexer

- Low loss plus extreme rejection ratio requirements limit technology choices, typically cavity filters (large and heavy)
- Advances fairly stagnant, a barrier to SDR-type tunability

A/D Converter

- Performance limited by dynamic range, typically 10-12 bits
- Increasing ADC dynamic range requires much higher power (4x power per 6dB dynamic range gain)
- Would require 30db (1000x) more dynamic range to do digital filtering to enable SDR-type tunability

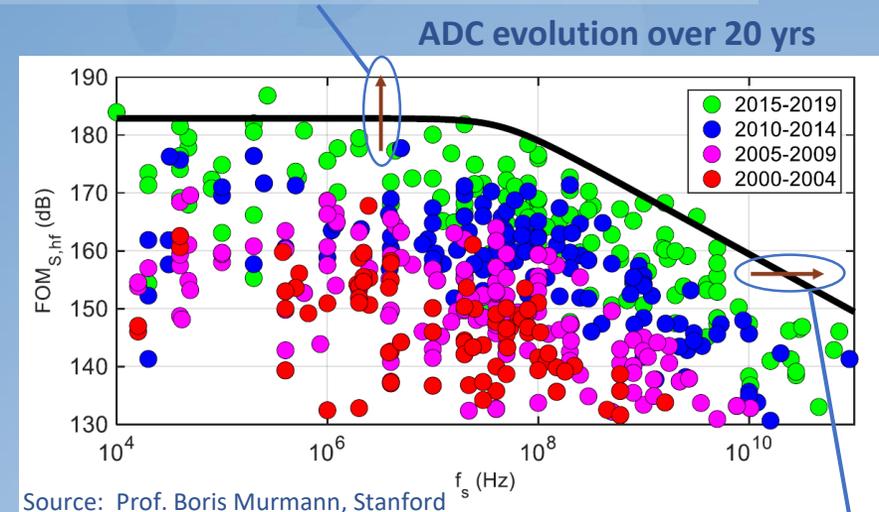
Oscillator

- Sampling clock jitter is critical for high speed ADCs
- SDR would require 15-16 bits at a few 100 GHz – such a low jitter clock would consume as much or more power than the ADC
- Jitter limit advances slowly (doubling every ~4 yrs) – the more limiting factor

Power Amplifier

- Significant contributor to power consumption/efficiency

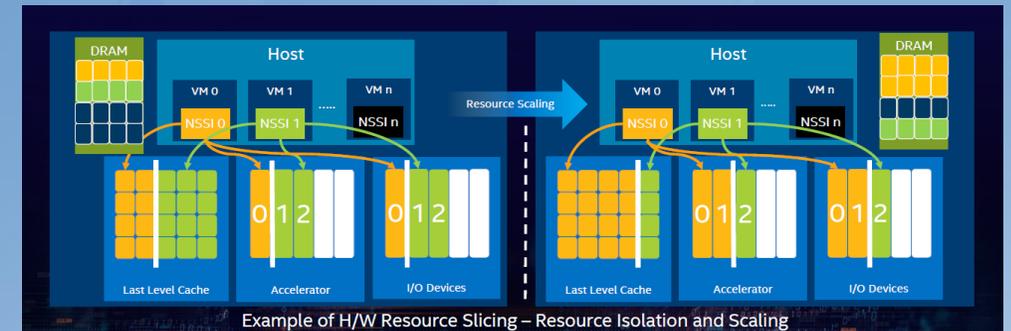
Low frequency (<100M samples/s) ADCs advancing ~1dB/yr, but approaching practical limit



High frequency (>100M samples/s) ADCs advancing ~2dB/yr, not up against a limit, but are less efficient

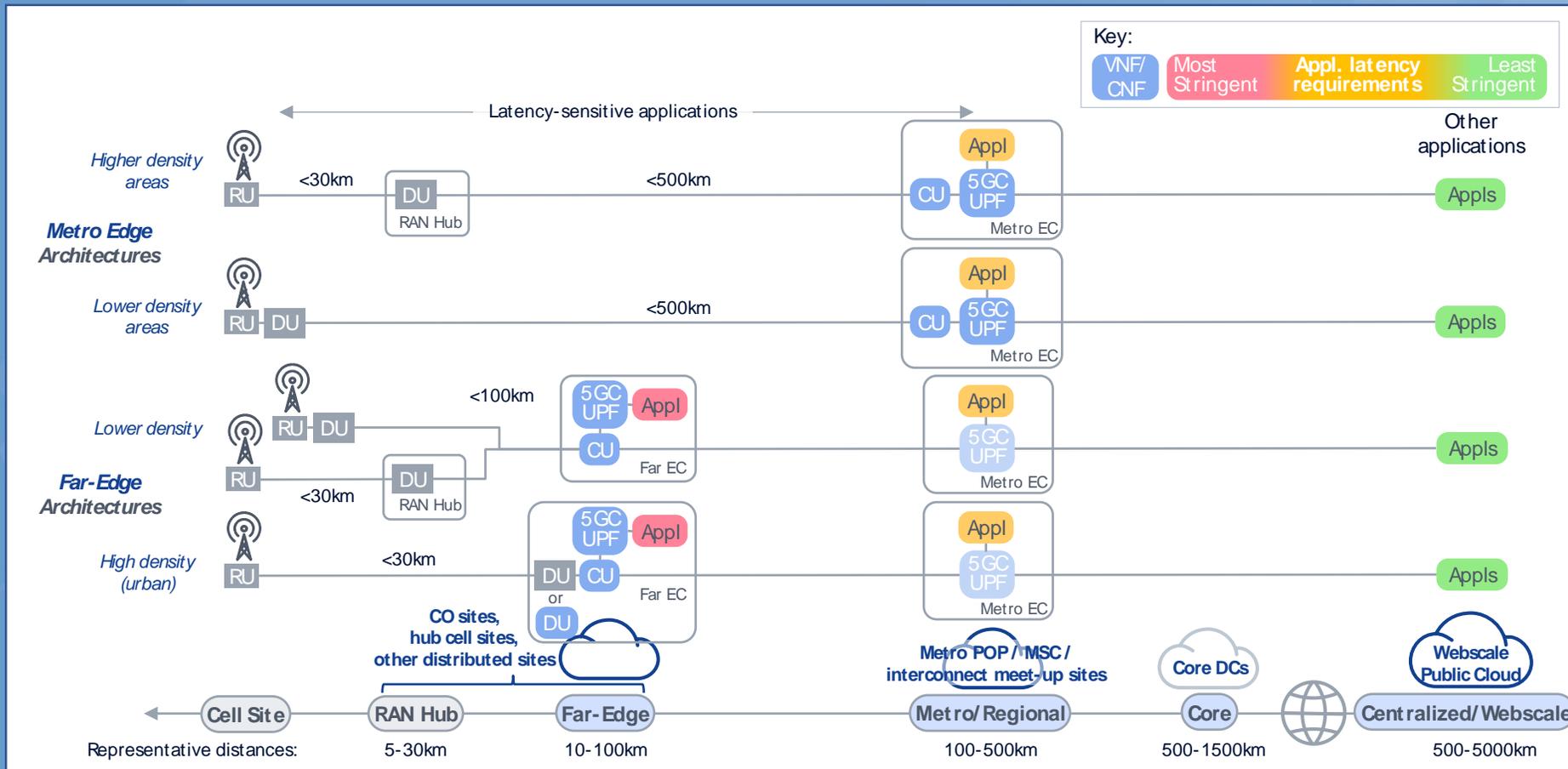
Key Insights – vRAN/Baseband Processing

- vRAN closely inter-related with Edge Cloud, E2E automation, O-RAN
 - Traditional and vRAN architectures will co-exist
 - Network functions evolving from bare metal -> virtualization (VNFs) -> cloud ready (CNFs) -> cloud native (microservices)
- Virtualization of lower-layer real-time parts of vRAN especially challenging, requires HW acceleration
 - Much progress made on real time optimizations for vRAN (isolation of RT tasks, kernel optimizations, I/O pass-thru mode, Smart NICs, etc.)
 - Meeting stringent URLLC latency and jitter requirements may be quite challenging
- Cloud scaling and feature velocity may be stronger driver today for vRAN than TCO savings
 - Cloud/software flexibility important for network slicing and a rapidly evolving technology
 - Pooling resources at all levels important for flexible network slicing (CPU, DRAM, caches, accelerators, I/O)
 - Mixed inputs on cost savings of vRAN (significant TCO savings claimed for greenfield Rakuten network in Japan)
 - vRAN value proposition is very operator-dependent (greenfield vs. brownfield, fiber resources, geographic density mix, etc.)
- Several variations of vRAN, depending on degree of virtualization and form of acceleration (see next slide)



Source: Intel

General 5G vRAN architectures (functional distribution)

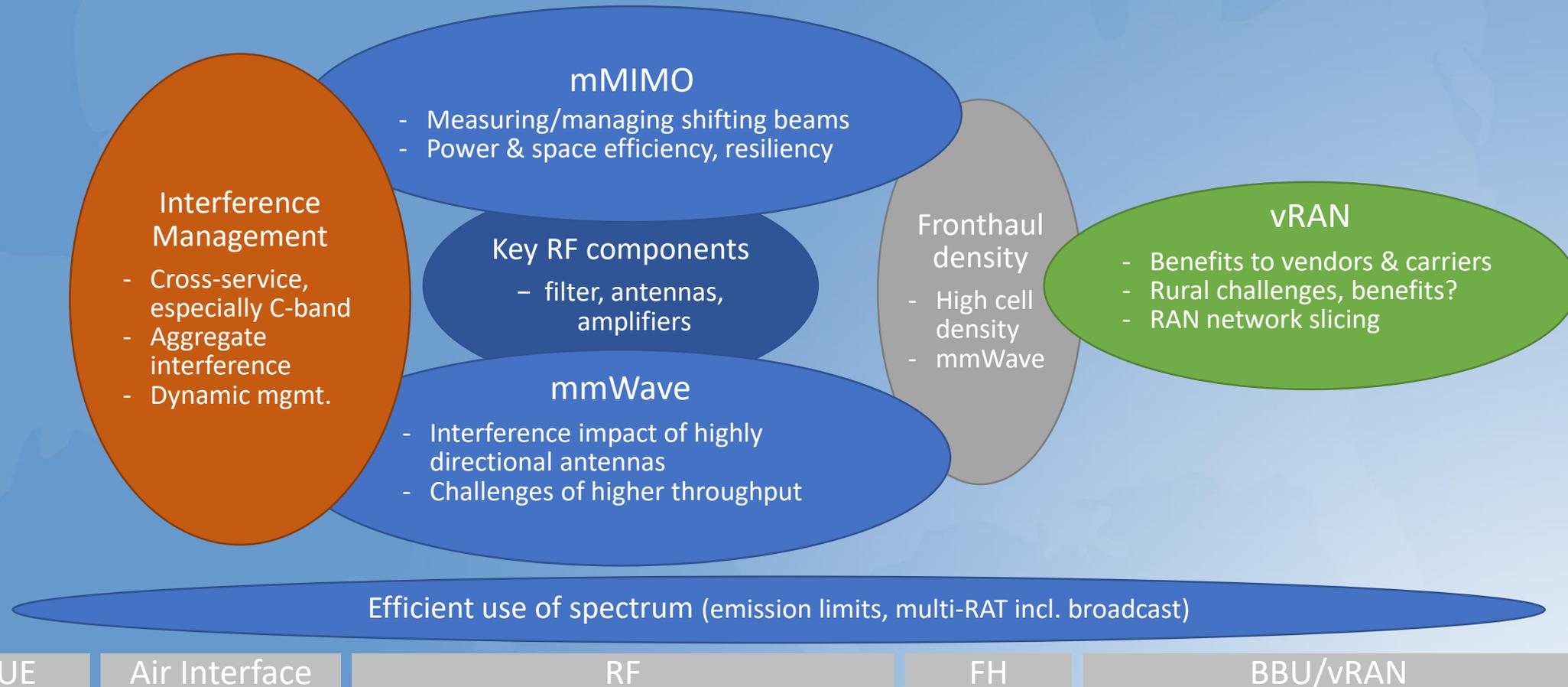


- Many variations
- Best fit depends on density, fiber availability and application needs
- All may co-exist in same network

Initial Observations – Interference Management

- Beamsteering and mMIMO beamforming challenges
 - Add many new degrees of freedom to optimize RAN performance, but ...
 - Creates a *much more dynamic* power distribution, channel conditions and cell edge overlap environment
 - This significantly complicates measurement of radiated power, and modeling of in-band and out-of-band interference
- Inputs so far suggest changes may be needed on how RF is measured & modeled for inter-cell interference and co-existence purposes
- Other factors such as predominance of TDD in higher bands may present further interference challenges
- WG activity in this area at early stage, and expected to be lengthy and complex

'Heat Map' of High Impact, High Interest Areas



Plan for next 'semester'

- Topics
 - mmWave: theory, technology, and operational experience (June)
 - Technology: filters, amplifiers, antennas (summer)
 - Interference management (summer/fall)
- Approach
 - Additional presentations
 - Internal TAC working group discussions
 - Develop key findings and recommendations

Thank You!



Technological Advisory Committee

June 4, 2020 Meeting

- Lunch Break -



Future of Unlicensed Operations Q2 2020 Report

WG Chairs: Kevin Leddy, Charter & Brian Markwalter, CTA

Date: 6/4/2020

Meeting: Virtual



2020 Working Group Team Members

FCC Liaisons

Monisha Ghosh
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Nick Oros
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Peter Ecclesine, Cisco
Aleks Damnjanovic, Qualcomm
Lynn Claudy, NAB
Nomi Bergman, Advance



Future of Unlicensed Operations Agenda

- Working Group Charter and Prior Work
- Value and Progress of Unlicensed Spectrum
- Subject Matter Experts
- Walkthrough of Findings and Updates
- Looking Ahead



FCC Charter for Unlicensed Spectrum Operations Working Group

- (1) How do unlicensed operations **complement or compete with licensed services**?
- (2) How can unlicensed operations **improve the user experience** and potentially become more competitive?
- (3) What are the **new services and novel applications** of unlicensed?
 - Are there **new protocols** that may improve the **spectrum sharing**?
 - Should the Commission **reevaluate certain regulations** to promote such novel applications?
- (4) How can we enhance the use of unlicensed operations while **sharing with personal radar** and
 - What are the enabling **technologies that may allow more unlicensed operations in more bands**?



Potential Findings Still Requiring Further Investigation

- **Light-touch regulation combined with industry standards** is still the best approach
- Low density (rural) and high density (venues, etc.) have greatest need for coordination and sharing
 - **Interest in expanding sharing of licensed spectrum** for rural use
 - Implement an incumbent **sharing model (like SAS) across more bands**
- Multi-system and multi-protocol environments (**coexistence**) **should be considered** from the beginning
- **Better metrics** to measure utilization of bands, interference, etc
 - Would help to understand whether new spectrum needs to be opened up, areas to further leverage existing via sharing or efficiency improvements, new business models
 - Metrics are often relative and must be evaluated appropriately (i.e. dense urban vs rural)



Encouraging Progress from 2015 Unlicensed TAC Recommendations

Key Finding

Unlicensed Spectrum use has grown enormously, especially with the rise of smart phones and tablets

Recommendations

Revisions to Part 15 rules are unnecessary at this time, but the Commission should continue to monitor

More unlicensed spectrum should be made available:

- Between 6 - 57 GHz
- >64 GHz

Promote more spectrum sharing

Consider rules to improve spectral efficiency as part of the rulemakings on additional unlicensed spectrum

Continue to rely on industry standards bodies to promote efficiency and co-existence

Progress

Minimal revision to Part 15 for unlicensed. Light touch approach has been huge benefit 

Addressed thus far by CBRS, 5.9 GHz, 6 GHz, and expansion of 60 GHz 

FCC is demonstrating via CBRS, Radiolocation, EBS, and 6 GHz 

Light touch regulation combined with SAS and AFC increase efficiency. Standards bodies are taking the lead on efficiency methods 

6 GHz and CBRS will be testing grounds as both will likely have large scale 3GPP-IEEE hybrid operations 

FCC has accelerated unlicensed spectrum allocations in recent years

1990

2000

2010

2020

1985

900 MHz

FCC authorizes ISM use between 902-928

2.4 GHz

FCC authorizes ISM use between 2400-2483.5

5 GHz

FCC authorizes ISM use between 5725- 5850

1989

Part 15

Part 15 is modified to allow conforming unlicensed use for any application

1997

5 GHz

FCC sets unlicensed rules for 5.15-5.25 (U1), 5.25-5.35 (U2A), and 5.725-5.825 (U3)

2001

60 GHz

FCC authorizes 57 – 64 GHz for unlicensed use

2003

5 GHz

FCC authorizes 5.47-5.725 (U2C) for unlicensed use

2016

60 GHz

FCC authorizes 64-71 GHz for unlicensed use

2018

CBRS

FCC finalizes rules for shared use of CBRS

2019

5.9 GHz

FCC issues NPRM to authorize 45 MHz for unlicensed

2020

6 GHz

FCC adopted rules for unlicensed 6 GHz operation



Presentation Summaries

Organization	Topic	Speaker	Summary
	Overview of Unlicensed Synchronization	Aleks Damnjanovic	<ul style="list-style-type: none"> Synchronous contention in unlicensed bands can reduce access latency and improve fairness and spectral efficiency in multi-technology deployments It is not necessary for all devices to conform to synchronous contention, but the more device do, the performance for all devices increasingly improves
	Overview of 2015 TAC Unlicensed Study	Brian Markwalter	<ul style="list-style-type: none"> Most 2015 recommendations were addressed to some extent While CBRS appears is a major highlight since 2015, 60 GHz has not delivered on expectations
	Broadband Access using License-Exempt Devices	Peter Ecclesine	<ul style="list-style-type: none"> Standards rely heavily on international alignment to become successful 5 GHz became mainstream only when phone manufactures started selling 5 GHz-compatible phones Scanning patterns of weather radar make U-NII-2 unreliable for unlicensed use
	Wi-Fi 6 and Global Wi-Fi Regulation	Alex Roytblat and Mark Hung	<ul style="list-style-type: none"> 802.11ax seeks to achieve real world gains: average 4x increase in throughput, reduced power consumption, better targeting of use cases Key enabling technologies include: OFMDA, Target Wake Time, BSS Coloring, MU-MIMO, and Beamforming
	Business Model for Unlicensed Spectrum	Derek Peterson	<ul style="list-style-type: none"> Boingo was an early adopter of DAS deployments Challenges with Wi-Fi and LAA co-deployments – technically co-exist but do not perform well on the same channel 160 MHz channels in public locations underperformed when compared with 80 MHz channels due to congestion and interference

Presentation Summaries

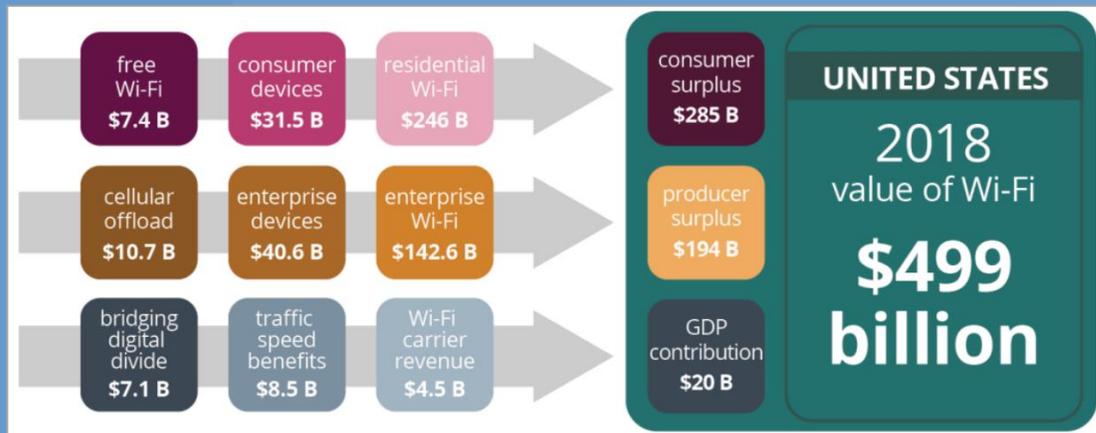
Organization	Topic	Speaker	Summary
	ETSI TC BRAN and Harmonized Standards	Guido Hiertz	<ul style="list-style-type: none"> Harmonized standards provide the linkage between industry standards and legislative rules (in this case, the EU) Unlicensed product certification in the US differs from the EU – FCC certifies unlicensed devices whereas companies self attest compliance to harmonized standard in the EU Detailed regulatory standards require similarly detailed compliance testing that covers all the details in the standards (as in the case with the EU harmonized standards)
	Rural Use of Unlicensed Spectrum	Claude Aiken	<ul style="list-style-type: none"> WISPs are typically independent operators. Often small business owners, farmers, etc living in rural communities where traditional ISPs may not operate WISPs operate on a range of spectrum, but favor unlicensed due to the prohibitive costs of acquiring licenses WISPs face two major challenges: capital and spectrum (congestion when sharing CPE receiving on unlicensed with in home routers)
	CBRS / SAS and Spectrum Sharing	Kurt Schaubach	<ul style="list-style-type: none"> Dynamic Spectrum Access is a software-based approach for allocating spectrum rights on a dynamic basis using data feeds and sensing devices CBRS SAS, while not perfect, is a leap from previous database-managed spectrum approaches (TVWS) Federated believes software based sharing should be opened up on existing bands wherever possible. Recommendation is to have FCC improve SAS/sharing technology review process

Question 1: How does Unlicensed Complement or Compete With Licensed?



Unlicensed Spectrum has Significant Economical Value to the US Economy

Unlicensed use spans all sectors of the marketplace, and is both a productivity tool and business model enabler



Source: Wi-Fi Alliance

According to the Wi-Fi Alliance, the value of Wi-Fi was **\$499 billion in 2018**, and is expected to reach **\$993 billion by 2023**

The FCC's proposals will create a wide array of economic benefits:



\$106 BILLION

Increase broadband speeds, accelerate deployment of the Internet of Things (IoT), and support the augmented reality/virtual reality (AR/VR) market—adding **\$106 billion** to the U.S. Gross Domestic Product (GDP);



\$69 BILLION

Allow producers to realize a producer surplus of **\$69 billion** based on savings on enterprise wireless traffic and sales of Wi-Fi and AR/VR equipment; and



\$8 BILLION

Produce **\$8 billion** in consumer surplus from increased broadband speeds.

Source: Wi-Fi Forward

Wi-Fi Forward estimates that 5.9 GHz and 6 GHz will add an additional **\$183 billion** to the US economy **by 2025**

Comparisons of unlicensed and licensed economic value are challenging. They complement each other in many applications while underlying competition remains.



Unlicensed Portfolio is Growing to Keep Pace with Demand

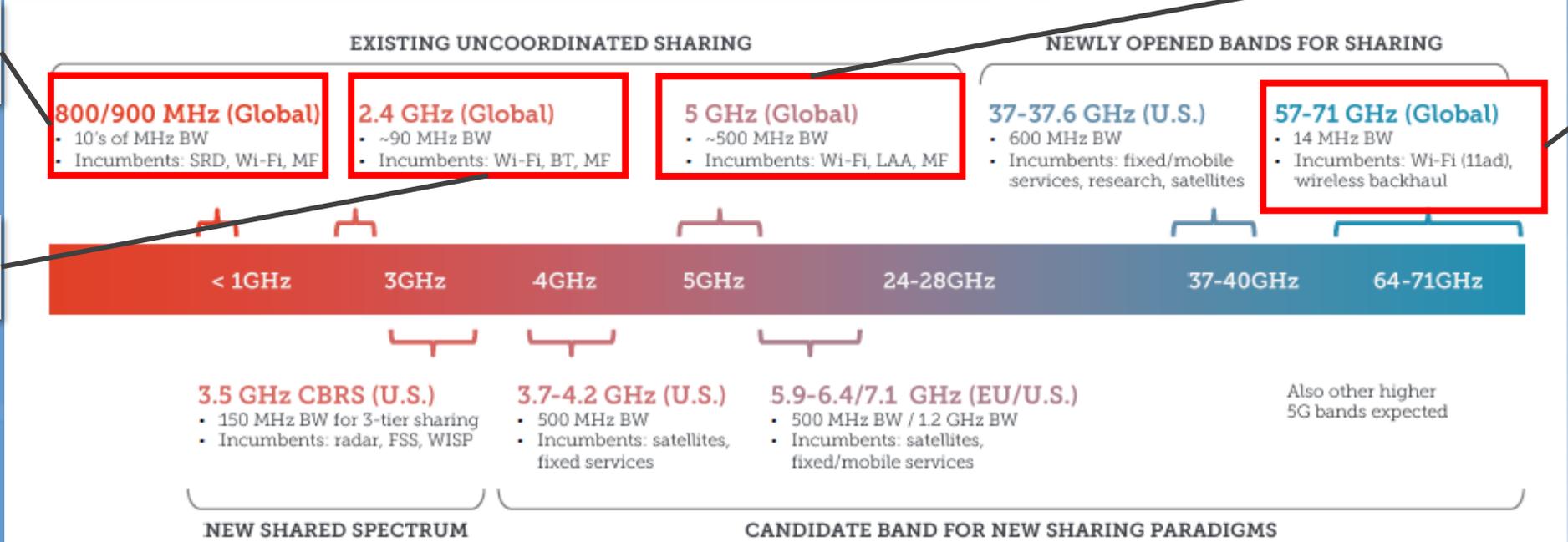
Spectrum availability needs to stay 5-10 years ahead of demand

Fast, suffers from DFS, becoming congested

WiGig in the US
Fast, large channel BW, propagates poorly (requires LoS)

Slow, congested, propagates well

Better speeds, highly congested



Source: Boingo

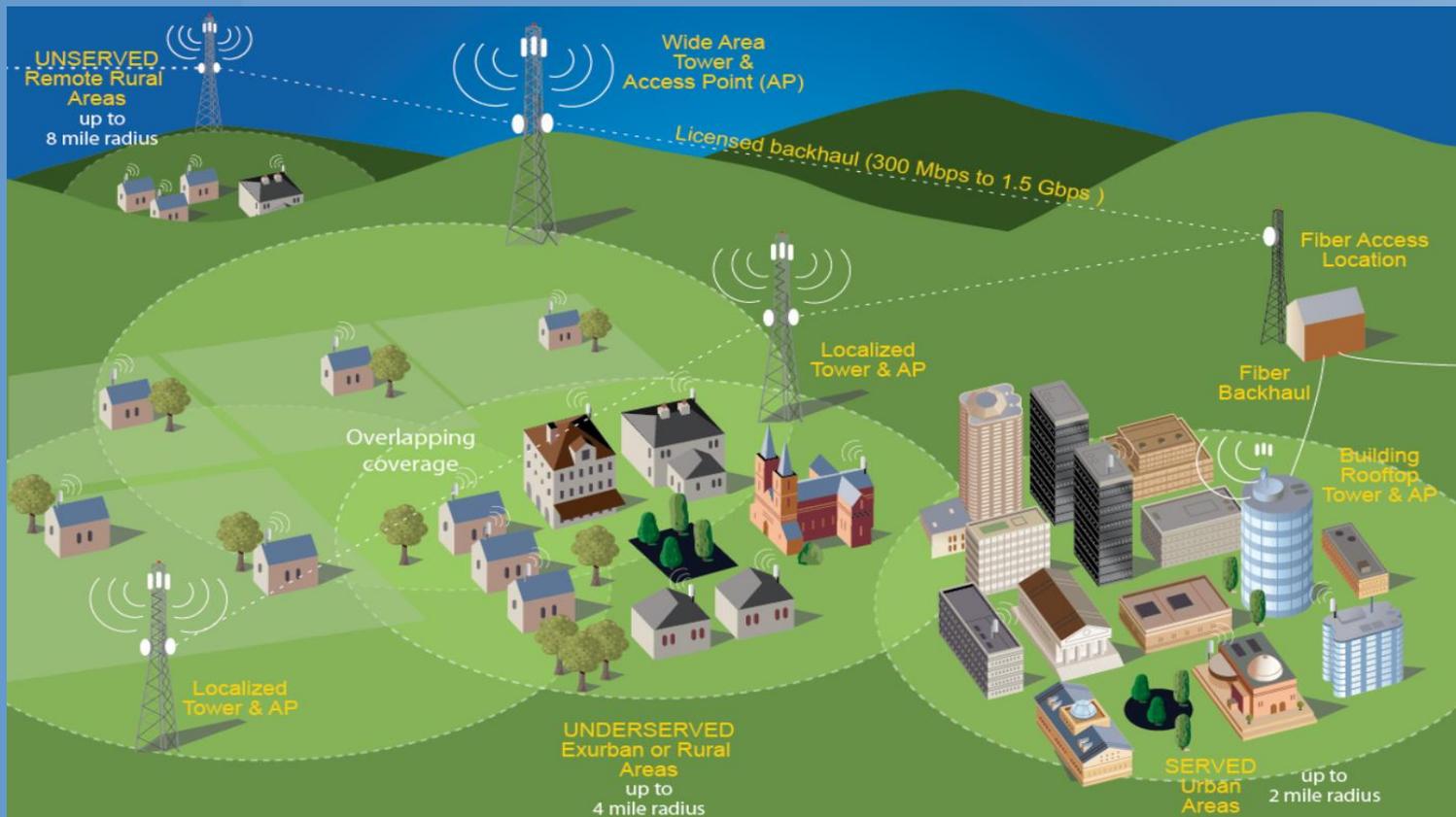
**Additional bands include TVWS and the modified 5.9 GHz DSRC



The working group plans to evaluate additional dimensions of unlicensed use (public vs private, indoor vs outdoor, etc)

Examples of Business Models Built on Unlicensed: WISPs

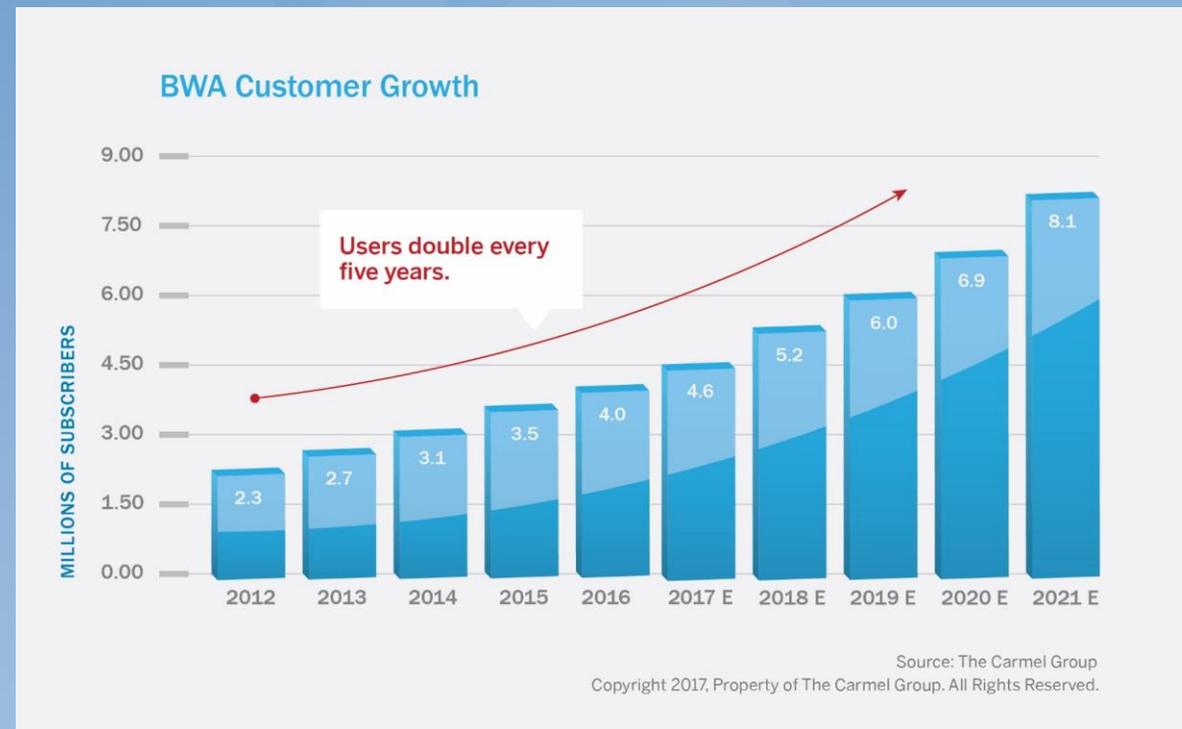
Limited Unlicensed Spectrum Constrains WISPs Speeds and Capacity



- WISPs often employ multiple wireless technologies and a tailored architecture for service delivery
- WISPs leverage a variety of bands including 900, 2.4, 2.5, 3.5, 5 GHz, and traditional licensed bands where available / affordable
- Planning to use 6 GHz

Examples of Business Models Built on Unlicensed: WISPs

- WISP operators are often small business owners operating in rural US
- WISPs are estimated to serve 8.1 million customers by 2021
- There are two main challenges faced by WISPs:
 - **Capital:** WISPs often seek unlicensed spectrum due to costs/complexity of acquiring licenses
 - **Spectrum:** face limited unlicensed options and often suffer from interference issues from competing devices



Examples of Business Models Built on Unlicensed: Neutral Host / DAS Provider

Boingo is a large scale adopter of unlicensed business models

Core Business

Boingo's core business is driven by three key areas: **Carrier Services**, **Military** and **Multifamily**



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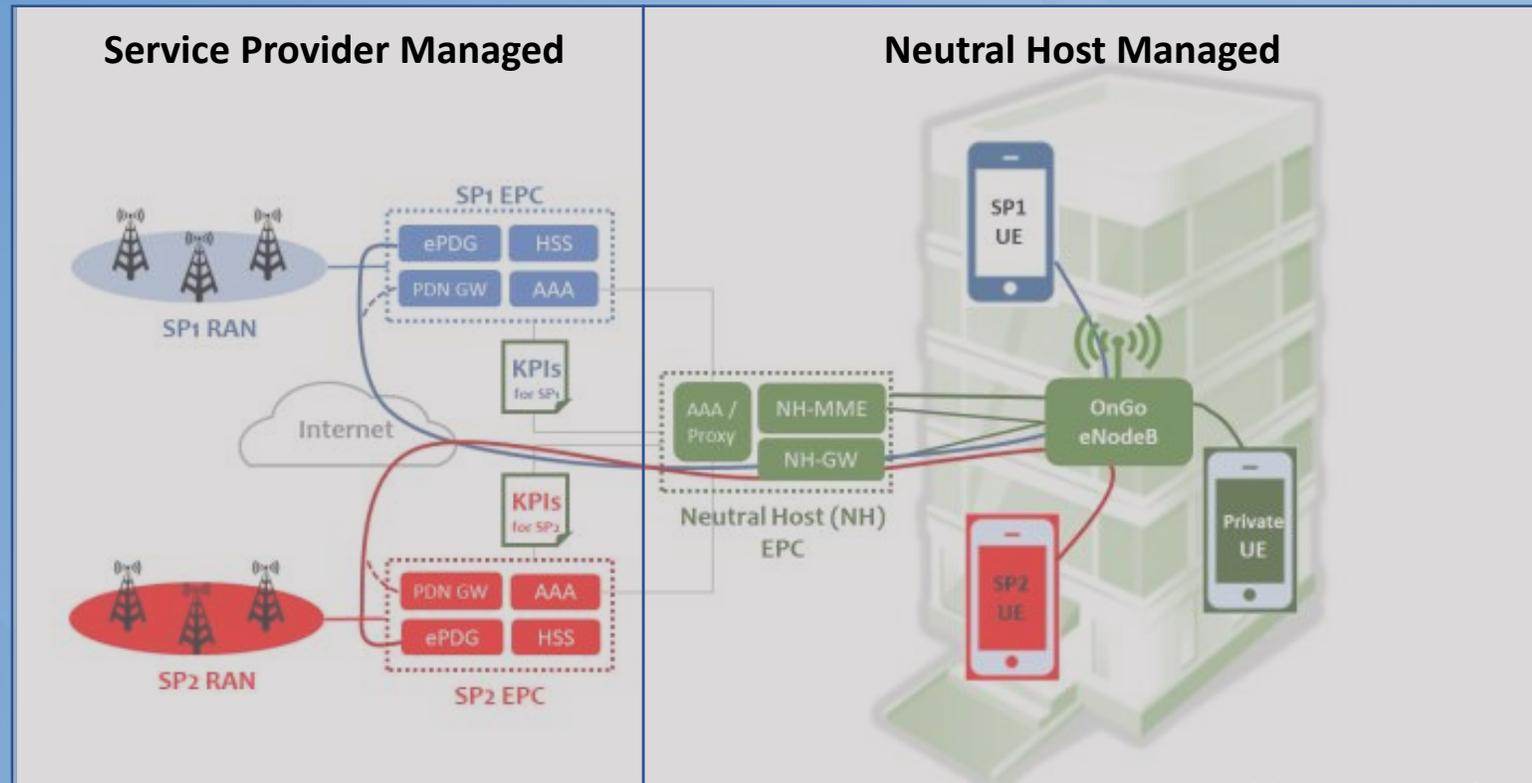
- Boingo has an operational model that heavily relies on:
 - Monetization of unlicensed spectrum
 - Hybrid licensed/unlicensed deployments
- These services span venues and businesses, college campuses, military, and residential



Examples of Business Models Built on Unlicensed: Neutral Host / DAS Provider

Neutral Hosting may emerge as an economical opportunity with new bands and technologies

- Neutral Hosting allows infrastructure owners to operate services and ISPs on common infrastructure
- Boingo via DAS has operated as a neutral host for venues and businesses for over a decade
 - Solves network management & ops needs for venue owners
- Neutral Hosting may have potential in rural, but the business model faces challenges:
 - Up-front CAPEX
 - Agreements with ISPs / MNOs
 - Questionable financial model
 - Lack of spectrum options



Source: CBRS Alliance

Question 2: How Can Unlicensed Improve the User Experience?



Wi-Fi 6 brings a new next wave of upgrades to unlicensed operations

- Enhance operations in both 2.4 GHz and 5 GHz bands
 - Improve the average **throughput per user** by at least **4x over Wi-Fi 5** in dense user environments
 - Up to **75% reduction in latency** over Wi-Fi 5
- Target indoor improvements: corporate office, dense residential
- Target outdoor improvements: hotspots, stadiums and traffic hubs
- APs **consume less power** than Wi-Fi 5 while supporting 4x throughput increase
- Maintain or improve power efficiency for stations
- Maintain compatibility with previous 802.11 MAC/PHYs
- Wi-Fi 6E will enable greater performance improvements via 6 GHz



Q3 / Q4 Reports Will Tackle Future Needs and Emerging Use Cases

- Initial interviews have helped to shed light on areas to improve unlicensed
- Further investigation is needed to understand the breadth of use cases, emerging technologies (Wi-Fi 6/7, 5G NR-U, etc), issues, and opportunities
- A deeper review of synchronization as a method for improving user experience
- A comprehensive update will be provided in future reports



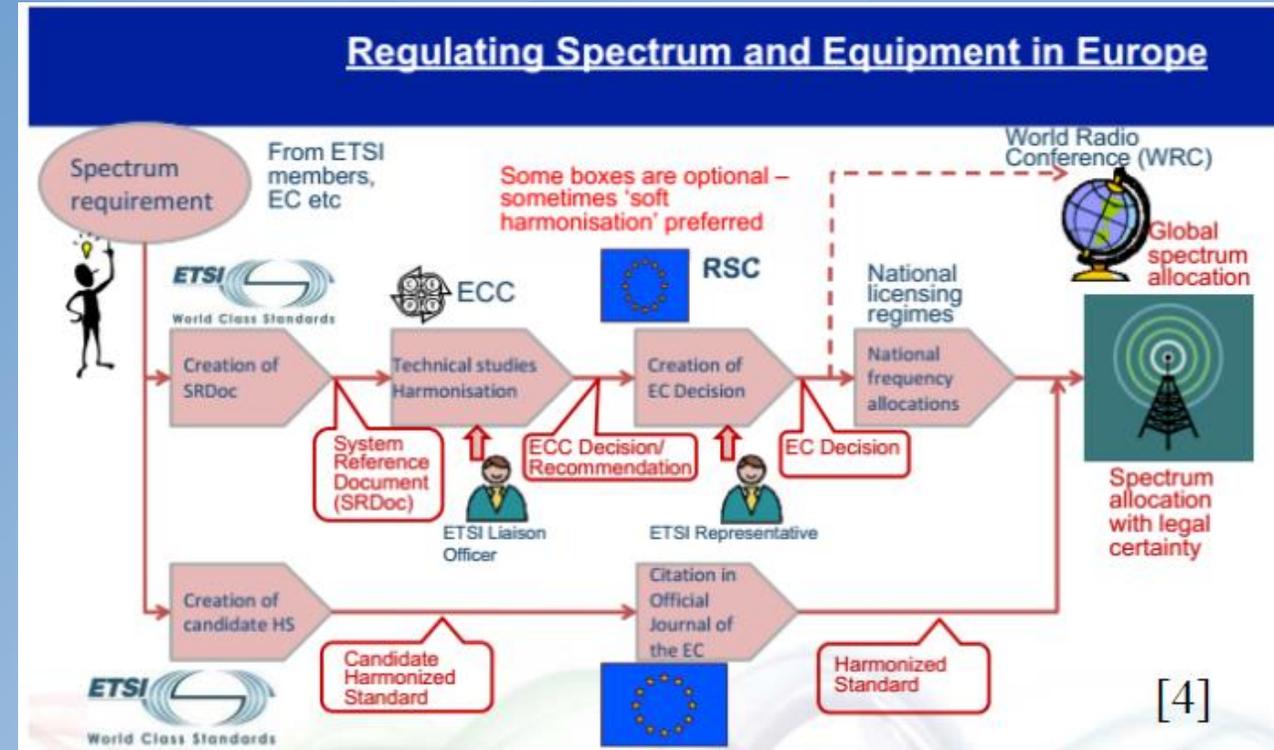
Question 3: What are the New Services, New Protocols, Regulations to Promote Unlicensed?



EU Rulemaking & Product Certification

Broader Rulemaking Scope, De-Centralized Certification

- In the EU, spectrum rules and product certifications are handled differently
- Generally, regulatory bodies allows manufacturers to self-attest as conforming to harmonized standards
- To accomplish this, **greater specificity is defined in regulations**

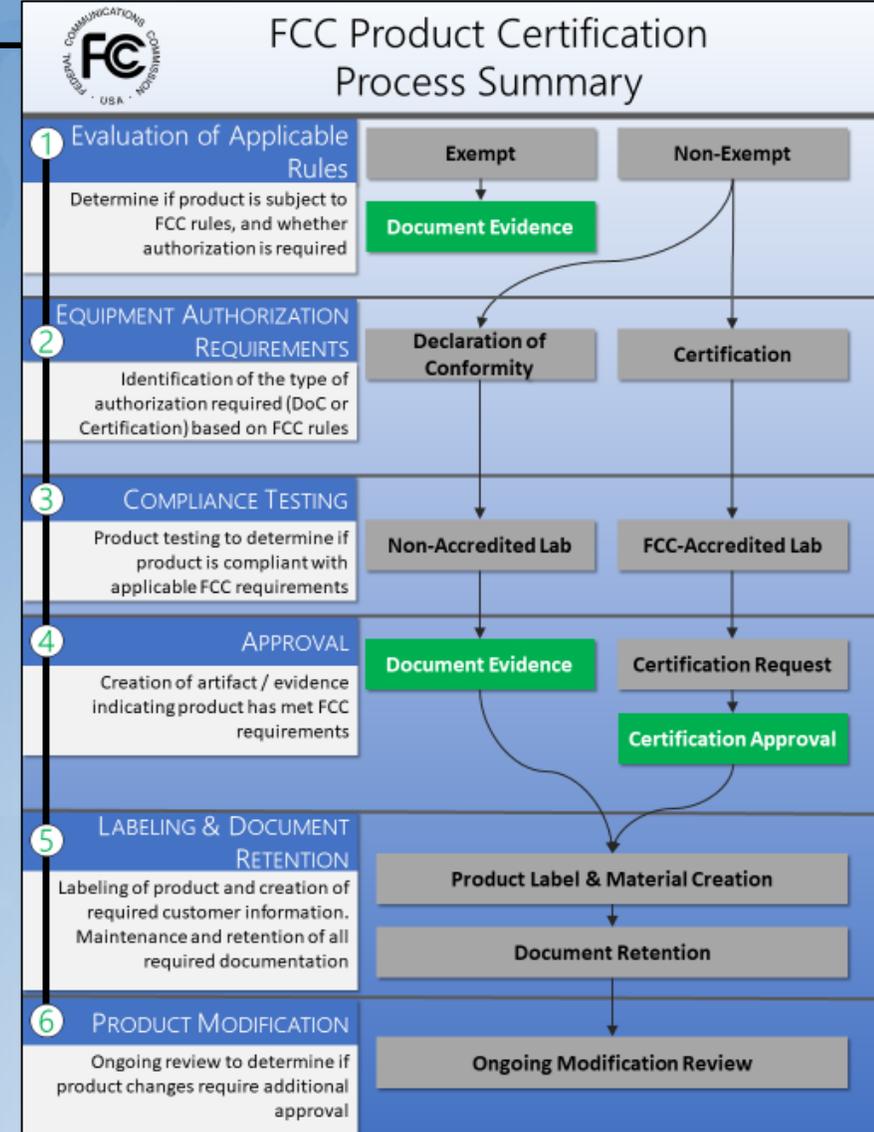


So What? So far, we've heard that US-based companies have benefited and tend to prefer the FCC's light touch rulemaking approach over the EU's use of harmonized standards

FCC Rulemaking & Product Certification

Centralized and predictable process

- In the US, the FCC has generally taken a “lighter touch” approach for rulemaking
 - Results in simpler technical rules
 - Allows for flexibility of use
 - Simplifies the modification process
 - Leans on industry and standards bodies for defining technical specifications
- RF-generating product certification follows a prescriptive process managed by the FCC as the central authority
 - Most products using unlicensed frequencies must be certified by the FCC



Current Unlicensed Standards Overview

	5G NR-U	802.11ax	802.11ay
Theoretical Speeds	Upcoming Speaker	Data Rate: 9.6 Gbps	Upcoming Speaker
Latency		<10 ms target	
Standards Completion Timeline		Current	
Estimated Market Maturity Timeline		2022	
Technology Advances		<ul style="list-style-type: none"> • Uplink and downlink OFDMA • MU-MIMO • Transmit Beamforming • 1024 QAM • Target Wake Time • BSS Coloring • Wi-Fi 6E allows for 6 GHz 	

Healthy technology sharing taking place between mobile and unlicensed standards

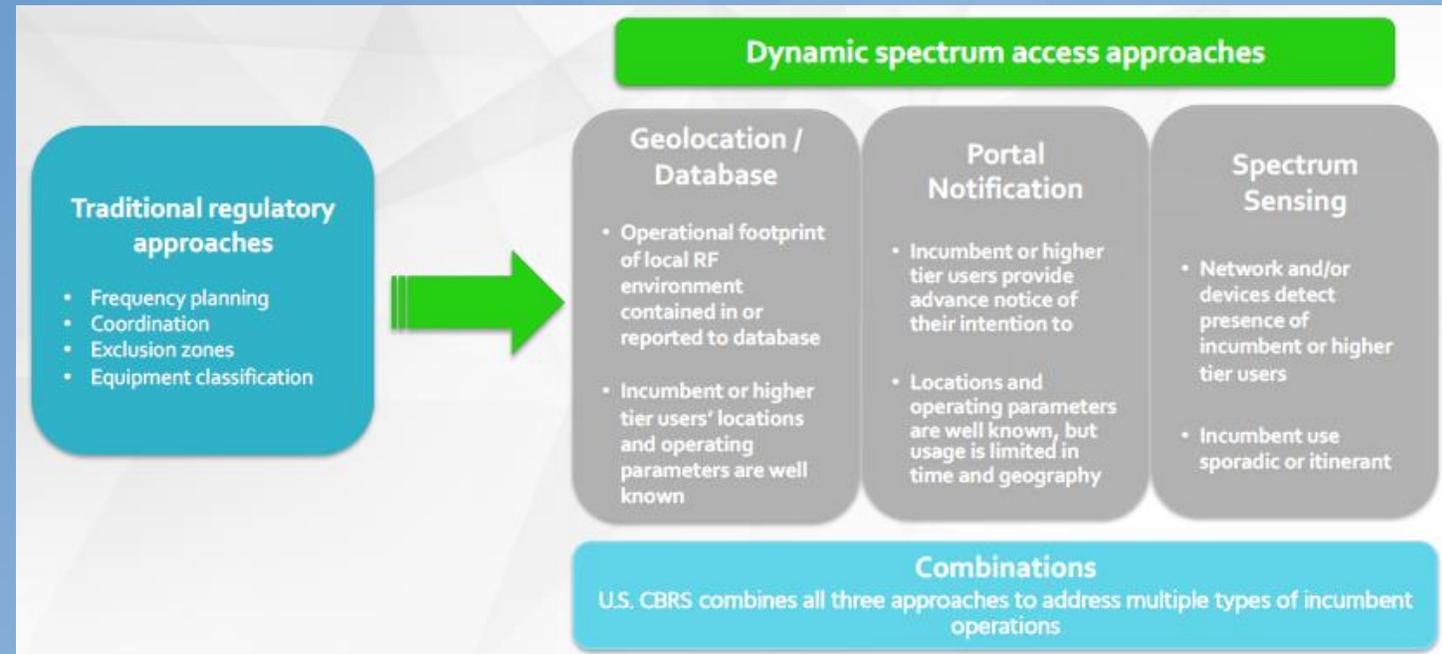


Question 4: What Sharing Technologies Enable Use with Personal Radar, Additional Bands?



As use of shared bands grows, so will the need for Dynamic Spectrum Access

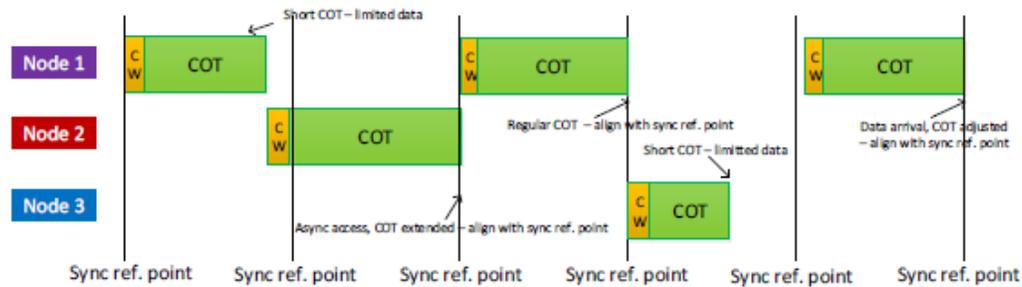
- Dynamic Spectrum Access is a software-based approach for allocating spectrum rights on a dynamic basis
- There are several approaches for implementing DSA, which can vary based on requirements, outcomes, incumbents, etc
- Benefits include:
 - Increase in spectral efficiency by allowing commercial users to existing bands
 - Increase competition and secondary marketplace
 - Maintain and protect incumbents
- Opportunities may exist to improve SAS/DSA certification processes and enable broader use of sharing



Source: Federated Wireless

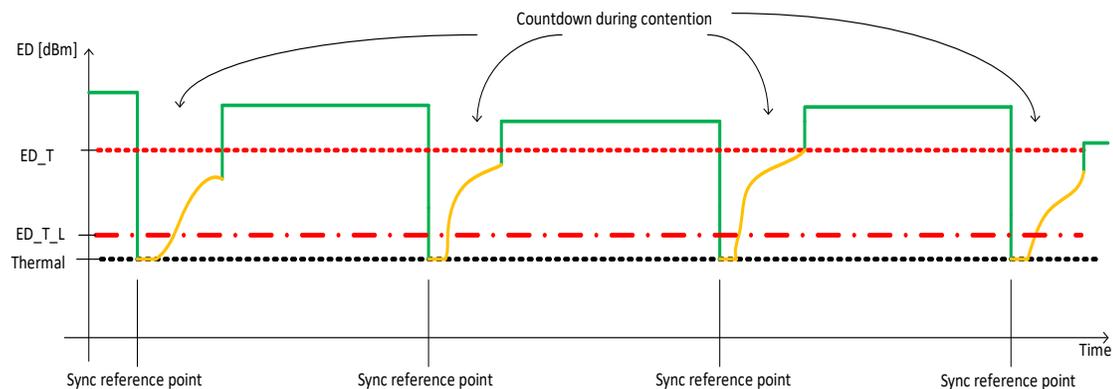
Advances in coexistence offers complementary and alternative sharing capabilities

Synchronized and Asynchronous Contention



Source: Qualcomm

Sensing of Licensed / Prioritized Users



Source: Qualcomm

- As 3GPP and IEEE coexistence will continue to be needed, opportunities exist to improve performance in hybrid deployments
 - Boingo provided real world feedback about challenges deploying 3GPP radios on the same channels as Wi-Fi
- According to Qualcomm, time-based synchronization may improve detection of licensed operation in co-deployment scenarios
- Synchronous contention provides frequent opportunities for contending nodes to sense the medium w/o experiencing interference from other contending nodes
- Synchronization is one of the several sharing proposals being investigated

Next Steps

- Deeper dive into standards (current and pipeline)
- Continue to investigate the relationship between licensed and unlicensed spectrum
- Finish evaluating current and future unlicensed use cases and the relevant technical challenges and spectrum needs
- Understand spectrum sharing technologies (current and future state) and coexistence, including with personal radar
- Investigate opportunities to improve metrics and interference analysis

Upcoming Speakers:



Chris Symanski



Michael Dunn



Andrew Clegg



Carlos Cordeiro



Rob Alderfer

and
more!



Thank You!



FCC TAC AI and Computing WG

Artificial Intelligence

Chairs: Lisa Guess, Cradlepoint
Adam Drobot, OpenTechWorks, Inc.

FCC Liaisons: Michael Ha, Mark Bykowsky, Monisha Ghosh, Martin Doczkat,
Robert Pavlak, Chrysanthos Chrysanthou, Gulmira Mustapaeva

Date: June 4, 2020



Agenda

- AI and Computing WG Members
- Calendar Year 2020 WG Charter and Objectives
- Approach to Objectives and Deliverables
- Summary of In Process Deliberations
- Potential Areas of Recommendation
- WG White Paper on AI
- Summary and Discussion



2020 Work Group Team Members

- Shahid Ahmed, Independent
- Sujata Banerjee, VMware
- Nomi Bergman, Advance
- Brian Daly, ATT
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- James Goel, Qualcomm
- Lisa Guess, Cradlepoint
- Russ Gyurek, Cisco
- Dale Hatfield, Univ of Colorado
- Stephen Hayes, Ericsson
- Mark Hess, Comcast
- Nageen Himayat, Intel
- Steve Lanning, Viasat
- Gabriel Lennon, Intern Univ of Colorado
- Kevin Leddy, Charter
- Anne Lee, Nokia
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Michael Nawrocki, ATIS
- Dennis Roberson, entigenlogic
- Marvin Sirbu, SGE
- David Tennenhouse, VMware
- Jack Nasielski, Qualcomm



Artificial Intelligence WG - 2020 Charter

The Artificial Intelligence (AI) and Computing working group will continue its work on analyzing the ability of AI to improve the performance of telecommunications networks and the services enabled by these networks.

To that end, the working group will focus on the following questions as outlined in the subsequent slides:



Objective 1

- How can the results from recent programs in AI for spectrum and networking, such as the DARPA Spectrum Collaboration Challenge (SC2) and the NSF/Intel joint solicitation on Machine Learning for Wireless Networking Systems (MLWiNS), be leveraged for real-world systems and applications and for investigating new applications?
- Examples:
 - Understand spectrum usage techniques to automatically identify signals, detect and understand violations
 - Assist with enforcement to prevent interference
 - Improve physical layer protocols and signal processing
- Actions:
 - Schedule top 3 winners from challenge as SME speakers – (lessons learned and formulation of use cases)
 - Use and exploit results from federally funded research programs

<https://www.spectrumcollaborationchallenge.com/> - DARPA Spectrum Challenge

https://www.nsf.gov/events/event_summ.jsp?cntn_id=299111&org=CISE - MLWiNS



Objective 2

- AI relies on curated and labeled data sets being available for algorithm development and testing: what should the parameters of such data sets be?
- Issues and questions to be answered:
 - What data sets are already available?
 - Use cases helpful to the FCC such as Broadband America
 - Datasets for congestion, provisioning, advertising, marketing are other examples
 - Center for Applied Internet Data Analysis (CAIDA) at UCSD curated data sets on Internet traffic and network routing which could be helpful for AI (And experience with collecting, disseminating, and curating Data)
 - How can new data sets be collected and made available to the community?
 - What is the purpose of the data?
 - Where can the data be used and by whom?
 - How can carriers be incented to share data and information for mutual improvement?
 - How can location data be shared without violating privacy (it's tricky!).
 - Helpful application example is CV tracking. (Israel is using cellphone surveillance to warn citizens who may be affected by individuals already infected – WP article)



Objective 3

- How can AI be used to extract meaningful information from data that are either already available (e.g. from the Measuring Broadband America (MBA) program) or may become available, to determine the following:
 - Coverage at a more granular level
 - Service parameters available in smaller coverage areas than census blocks
 - Merged or Aggregated with other data to detect fraudulent activities such as unauthorized spectrum usage



Objective 4

- As legitimate applications of AI start proliferating, what risks should be evaluated and what AI tools exist or should be developed to identify and mitigate harms that might arise from the proliferation of AI?
 - How to promote safe use of AI?
 - How to deter deleterious use of AI?
 - How to build in robustness into the AI Methods and Techniques used?



AI WG General Approach

- Develop use cases and important issues where AI has a potential impact on the FCC, the national Telecommunications ecosystem, and can be an enabler for significant new economic activity.
- Conduct Weekly meetings of main WG and integrate input from two SWGs
 - Safe Use of AI – SWG Input
 - Lessons from Federally funded AI – SWG
- Study issues and use cases leveraging industry experts, analysts, government organizations, and the research community and gather relevant background data (Appendix 1 contains a list of currently scheduled speakers)
- Categorize and prioritize use cases and issues (based on relevance to the FCC , the industry, or end users, likely level of impact, and time frame to maturity)
- Understand use cases in context of AI WG Charter and the four objectives
- Work Product for AI WG in 2020
 - Final Presentation
 - Actionable recommendations aligned with the four objectives by Dec 2020
 - Whitepaper: The potential for useful applications of AI in Telecommunications and Appendices



In Process Deliberations: Lessons from Federally Funded AI Research – Objective 1

- Approach:
 - Contribute to recommendations on the impact of AI/ML techniques in areas of relevance for FCC
 - Identify relevant technologies developed as part of federally funded research, emphasizing technologies that will be mature on a 3-5year time frame.
 - Specific Outputs – Presentation and white paper
 - Using Federally Funded AI Research, focus on areas such as Spectrum, rural coverage, adversarial ML, 5G+ enhancements, privacy, process improvements
 - Include Impact of testbeds such as NSF PAWR platform on developing AI for networking
- Potential areas of recommendation:
 - FCC needs to prepare to exploit research for policy and rule making
 - Challenge – FCC does not have a research charter and relies on other agencies
 - NIST, NTIA: Long term, FCC may want to include research and development activities related to engineering and spectrum management within its strategic plan



In Process Deliberations:

Lessons from Federally Funded AI Research – Objective 1

- Draft recommendation: FCC should receive funding from Congress for the purpose of independently evaluating network performance.
- FCC general charter: Has 9 titles stemming from communications act (1996).
 - Not responsible for consumer protection, but deals with network outages (analyzing outages, real-time issues). Consumer policy (handled by FTC, Consumers protection bureau)?
 - Deals with health of networks
 - Act 1934 act may allow it to do more? 1996 amendment ? → Mission (titles)
 - Spectrum, wireless/wired, health of networks, protecting consumers and safety, ensure access to communications.
 - FCC should analyze the impact of AI on networks (evaluation tools are missing).
 - FCC technical side = 200 people. Research infra does not exist.
 - FCC's general charter does not allow for direct funding of research and analysis projects. Potential actions to enable such projects include (a) request to expand the charter, (b) potential partnerships with other agencies to drive the analysis



In Process Deliberations: Data Sets - Objective 2

- How will relevant data sets be made available while maintaining privacy, competitiveness, and value
- How shall Data Sets be organized?
 - Existing Data Set examples: NIST framework, EU framework
 - Network-oriented example – Leverage the OSI stack, because L1-7 aligns with how networks are built and architected
 - Other lenses
 - Value cut - Lifecycle of data – oriented around producers, consumers, transporters of data.
 - Vertical cut/Application cut – oriented around the needs of the industry



In Process Deliberations: Data Sets - Objective 2

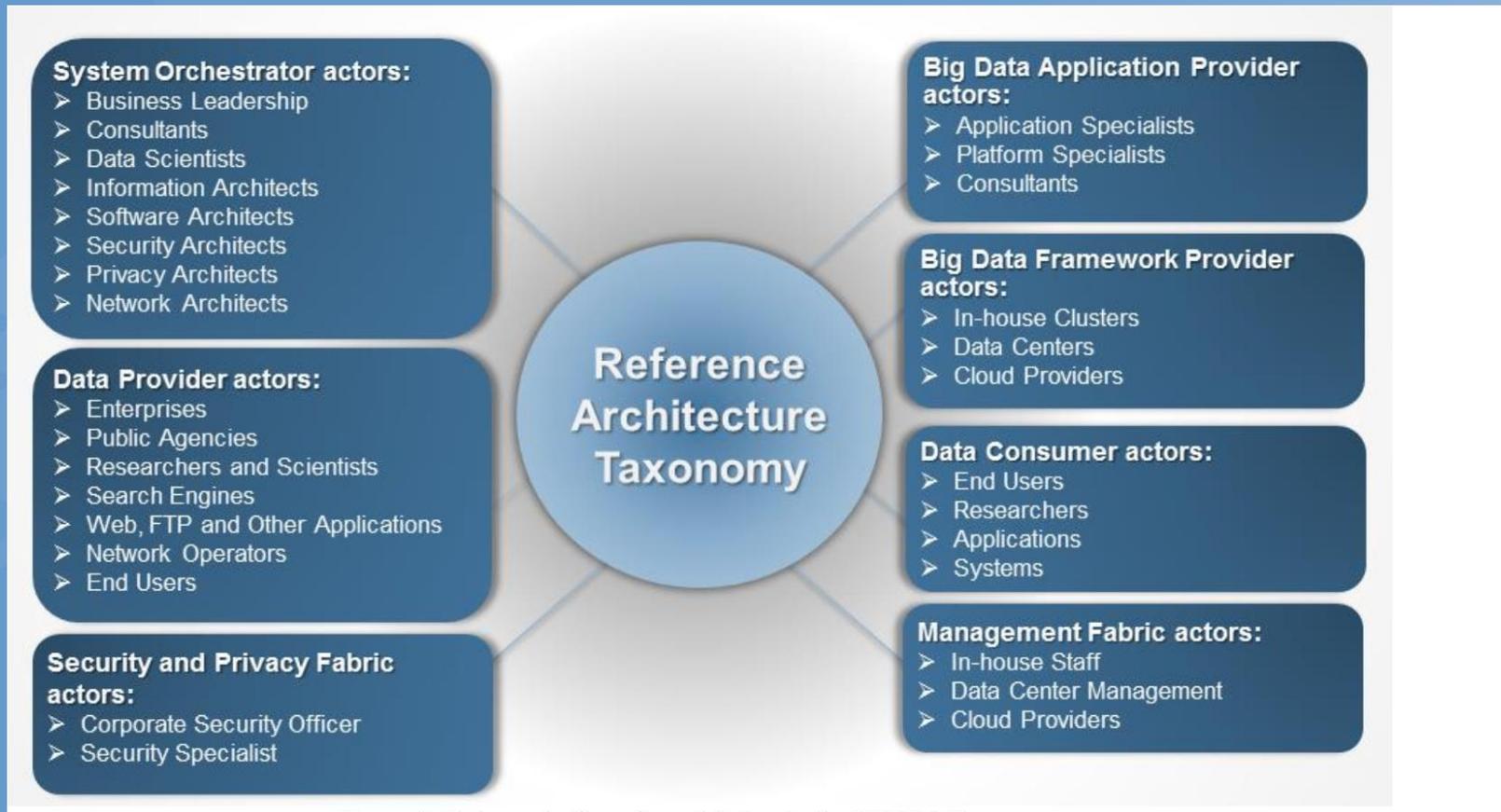
NIST Big Data Interoperability Framework: Why?

- There is broad agreement among commercial, academic, and government leaders about the remarkable potential of Big Data to spark innovation, fuel commerce, and drive progress.
- Big Data is the common term used to describe the deluge of data in today's networked, digitized, sensor-laden, and information driven world.
- The availability of vast data resources carries the potential to answer questions previously out of reach, including the following:
 - How can a potential pandemic reliably be detected early enough to intervene?
 - Can new materials with advanced properties be predicted before these materials have ever been synthesized?
 - How can the current advantage of the attacker over the defender in guarding against cybersecurity threats be reversed?



In Process Deliberations: Data Sets - Objective 2

NIST Big Data Interoperability Framework: Taxonomy



The Framework is not currently Telecommunications or Networking specific!!!



In Process Deliberations: Data Sets - Objective 2

OSI Model as a Data Set Framework

- Physical Layer
 - Propagation statistics – there are a huge variations and simply dealing with averages is not useful. "Closing the Interference Loop"
 - Traffic volumes, Error rates, etc.
- Data Link Layer
 - Channel quality – Signal to Noise Ratio
 - How much throughput exists - /Bps/Hz
- Network, Transport, Session, Application, Presentation all have data sets
- Challenges with this approach
 - Geographic points are missing from this viewpoint. This is important to spectrum.
 - Traffic between A&B

Examine alternate organizing principles such as the AI Value Chain



In Process Deliberations: Data Sets - Objective 2

Data Sets – Other Considerations

- Privacy and trustworthiness are critical considerations and impact availability of the data
 - For example, mobile data the FCC holds has geo data, but creates privacy concerns
 - Best practices balance geo data against privacy through levels of anonymization, or even extrapolation from AI model output to AI model input. You don't have to access the source data down the chain, you can leverage the output which by its nature is opaque.
 - The use of Privacy Preserving Distributed ML techniques may be beneficial (Example: Linux Foundation's Federated model)
- Access to recent data is a challenge. Data that is public is much older (sometimes 50 years) in order to maintain privacy.
- Are there worthwhile incentives so that companies are inclined to share for the mutual good? (this is a potential recommendation – using an open source type of model has been suggested)
- Not all data has to be created from scratch. Iterating on output of other models may help to mitigate privacy concerns. Companies may be incented in different ways. Public vs Private. In the public world, there is a natural incentive due to grants money. In the Private world, there can either be advantage to the company strategically, or monetarily.
- Also to consider – what is the most useful data to gather to improve and calibrate models?



In Process Deliberations: Broadband Mapping and AI - Objective 3

- Identification of the proportion of locations that have access to the maximum advertised broadband service. Requires greater granularity than a census block. What is unserved (less than 25Mbps) in a census block that shows greater than 25M is an important data point.
- The Broadband DATA Act, enacted earlier this year, requires the FCC to implement a polygon shapefile collection of areas where broadband is deployed
 - This is significantly more granular than census block level reporting.
 - The new law calls for the shapefiles to be overlaid on a highly detailed Broadband Location Fabric (BLF) that will identify, at the parcel level, every structure that should have service.
 - Crowd-sourcing is also addressed in the law.
 - The FCC is waiting for appropriations so it can begin the process of determining how files should be submitted and issuing an RFP for the BLF
 - Affordability is an adoption issue and not a deployment/availability issue (the two should not be conflated and have different solutions)
 - Is the unserved based on a model or a more direct method?
- What technologies exist to point out these areas, and do not to delve too deeply into privacy issues?



In Process Deliberations: Broadband Mapping and AI - Objective 3

- Identification of the proportion of locations that have access to the maximum advertised broadband service. Requires greater granularity than a census block. What is unserved (less than 25Mbps) in a census block that shows greater than 25M is an important data point.
 - What does the map look like? Why? Affordability, and Geography as issues.
 - Are the underserved based on a model or a more direct method?
 - Sources of data – ICT Companies have private awareness WAN structure, data, and performance (including WISPs and Satellite Operators). Overlaying competitive pricing data alongside the choice of carriers can inform what is serviceable vs what is not serviceable. How can the data be shared? Do there have to be incentives? The data isn't public. Can this data be crowdsourced? Purpose is just to inform – not to advocate any position.
 - What technologies exist to point out these areas, not to delve too deeply into privacy issues.
 - How much of the access is wireless vs fixed and where is satellite access?



In Process Deliberations: Broadband Mapping and AI - Objective 3

- NTIA/NTIS is doing modelling. Drive test measurements are used for planning.
 - Other sources include companies such as Hawkeye 360 – Satellite company looking at bands, bases stations, etc.
 - How can this data be used in an AI context? The data is a training set, and prediction will be involved.
- The WG should be mindful that AI is not the answer to everything but may be part of a larger solution.
- How can AI be leveraged to fill in the map so more access is available to more?
 - Availability of educational services (includes compute, storage, and connectivity). Same for healthcare, first responders...
- FCC has a large fund to solve a lack of ubiquitous BB. How are decisions made to allocate funds?
- Why would we leverage AI? What can it give you that you can't get any other way? Will it be effective?



In Process Deliberations: Safe Use of AI – Objective 4

- More investigation through the end of year. First half of year focusing on other 3 objectives. A significant number of speakers scheduled remainder of the year on this objective
 - Issues to be addressed:
 - Trust
 - Security
 - Privacy
 - Formality of Software Development and Analysis when using AI tools
 - Completeness and appropriateness of learning data sets
 - Robustness of AI Algorithms
 - Testing Methodologies
 - Avoidance of Vulnerabilities and misuses of AI
 - Public reaction and acceptance



Summary of In Process Deliberations

- Lessons from Federally Funded AI Research (Objective 1)
- Characterization of Data Sets (Objective 2)
- Broadband Mapping and AI (Objective 3)
- Safe use of AI (Objective 4)
- Broad topics
 - AI and Spectrum Management
 - AI and Customers
 - AI and ORAN
 - Network Operators, Equipment and Software Providers, and AI – management and control



In Process Deliberations: Broad Topics

AI and Spectrum Management

- Spectrum management: Enforcement and interference avoidance. Investigating additional insights on FCC activities
- Use of AI tools to help us with what is safe and what is not
- Within Network Providers themselves – slicing, dedicated spectrum facilitated by AI
- Mitigation and interference issues with AI
 - Detect and Classify
 - Locate and Report
 - Mitigation
 - Consequences
 - Look for broad patterns as well as individual offenders
 - Broad patterns can help to define best practices
 - How can this information be shared across multiple entities (researchers)
- Leverage papers and other literature for this knowledge plus Subject Matter Experts
- Federal initiatives that have potential to inform in this area include (a) DARPA spectrum challenge, (b) NSF programs related to spectrum research, including MLWINs



In Process Deliberations: Broad Topics

AI and the Customer

- How is AI being used to deal with customers? Two aspects – using AI for marketing their services, and the customer care space? How does the use of AI impact call centers and structure/chatbots? Is AI being used to pre-emptively solve customer issues?
 - MSO example: steps taken to make digital assistants more available have helped the MSO and customers in this current difficult time. Despite an assumption that complaints would increase with the use of AI and digital assistants, the opposite was true. NPS scores increased...so customers are more satisfied with many of the self-service and automated solutions.
- AI in tools for service offerings
- Troubleshooting
- Is there the possibility of an offering using AI to measure WFH productivity?



In Process Deliberations: Broad Topics

AI and ORAN

- Open RAN – what are our various organizations we represent doing with AI in this space? Note: There is a working group inside ORAN responsible for AI. Any insight on their efforts? Who has what kind of data and how would you organize a framework about what kind of data is useful for various applications of AI?
- ORAN Alliance is building OS code, but AI was not a core function at this point. Spectrum management perspective is important to cover. It is clear, that many more licenses could be offered via a “data-driven management SAS implementation” vs the more conservative geographical based rule-set.
- How do you use AI/ML? What kind of data is necessary to train?



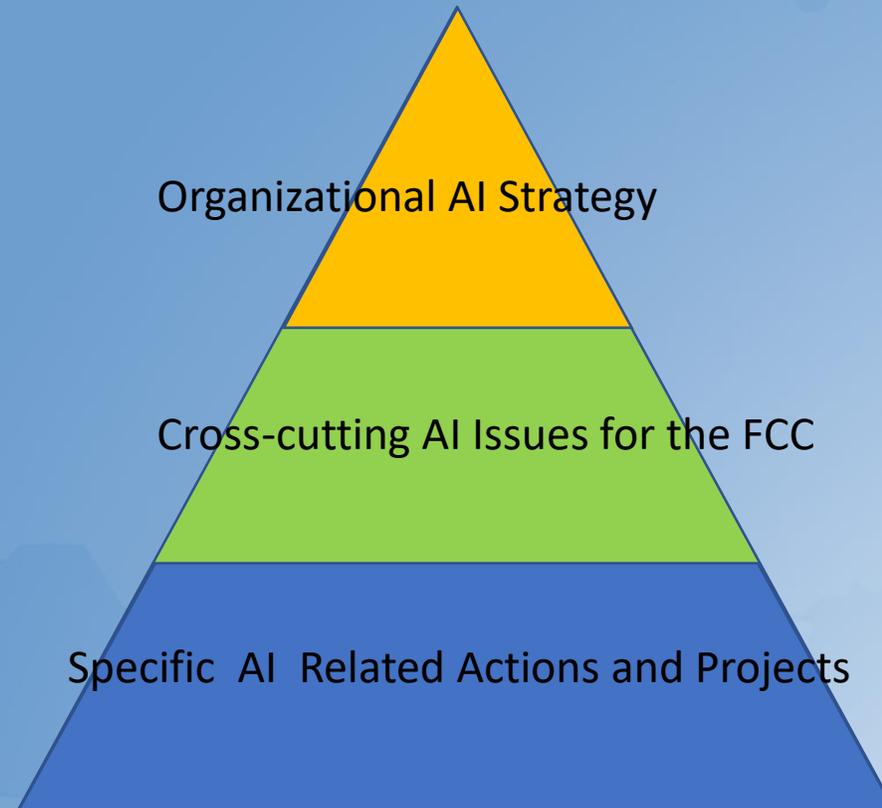
In Process Deliberations: Broad Topics

Network Service Providers and AI

- How are they using AI for management and control? Are they doing their own work internally or is there a body of work emerging across the industry? Is it open to others or are they all working with generally the same vendors?
- Would these vendors be useful to reach out to? Topics of interest are forward looking use of AI. i.e. Security, Network slicing
 - Ericsson speaker – Exposed us to a very broad set of applications using a variety of AI techniques.
 - Identified announcements by Network Operators of AI as a service offerings – need to cover!
 - What plans do other Service Operators have in this area and what are their plans for more?
 - Systematic research of peer reviewed publications and white papers might be helpful – (Summer Intern)
 - Understanding of industry, possibly including AI in troubleshooting
 - Identification of potential speakers
 - What search terms should we use? AI, propagation modelling,
 - IEEE website on this topic gathering various literature, patent literature
 - <https://mlc.committees.comsoc.org/research-library/> This is the Comsoc digital library for AI for communications
 - Output – current bibliography



Potential Areas of Recommendation



Potential Areas of Recommendation

Actionable Recommendation areas for investigation (to be prioritized)

- High Level Recommendations
 - How does the FCC internalize the implications of AI and is prepared to deal with the consequences of deploying AI widely. How does it build its capability and capacity to deal with the issues? What does it take to be successful in a concrete way. How can an organization be prepared for that?
 - Main Recommendations so far: FCC should receive funding from Congress for the purpose of independently evaluating network performance
- Cross-cutting AI Issues for the FCC
 - AI and security, privacy, trust, assurance
 - AI and outage analysis, root cause, preventive maintenance, repair and recover best practices
- Specific AI Related Actions and Projects
 - Data Brokerage – how do you incent companies and stakeholders to share data while maintaining privacy and competitive balance?
 - AI to understand propagation
 - AI for Broadband Mapping
 - Align the working group on data set categorization – types, alignments, interoperation
 - AI to drive marketplace for interference credits



White Paper Specific to AI in Telecoms

Potential AI Applications in Telecommunications

- Sample topics
 - 3GPP
 - Input from Industry Analysts, ACUMOS, OpenRAN collaboration
 - Security considerations
 - Implementation Best Practices
- High level Framework of all the areas for AI in networks including a timeline of what is mature and what is not
 - This will help frame recommendations and focus on the actionable time frame (3-5 years)
 - Roadmap for AI in the communications area. The goal is to be informational and provide additional judgement on the maturity of various AI aspects
- Format: One WP with standalone subsections from each of the sub WGs
- Will include recommendations that come out of WG, and specifically address impact to FCC
- White paper will include sources that capture trends, details, and measurement in Appendix.
- Under consideration
 - Should Allocation of Spectrum be included as it relates to AI?
 - Should Ethical issues be a part of the white paper? (Two lawyers in this area will be speaking to the group)



Summary and Discussion

“Be Ready” *We looked at a lot of generic aspects of AI last year. This year we are focusing on topics that are important to the FCC, to the Network Providers, the Equipment and Software Providers and to end-users. As we have gotten into the material, it is obvious that the issues around AI will impact the FCC across a broad front. To reinforce – it is important for the FCC have a strong and well-articulated strategy for how it deals with the impacts – positive or negative that AI is likely to have.*

“Fair Warning” *There are issues concerning the use of AI that are likely to land in front of the FCC. This is likely to happen regardless of whether it is in the FCC charter, it will fall to the FCC to deal with the outcomes and ramifications. It is important to have the FCC internalize and broadly understand and be prepared to deal with such issues.*

“Carpe Diem” *Much of the world is using AI. Many analysts rate the Telecommunications sector as leading in the use and exploitation of AI. For the FCC it is an opportunity to lead too!*



Appendix 1.
Speaker Schedule



April - May

Date	Speaker	Title/Topic		Address
April 29th	Ulrika Jägare Ericsson	“How AI is Shaping Telecom Operations”	A broad perspective where AI is currently in use	ulrika.jagare@ericsson.com
May 6th				
May 13th	Mazin E. Gilbert AT&T Research			mazin@research.att.com
May 20th	Mukarram Bin Tariq Nandita Dukkipati Google			mukarram@google.com nanditad@google.com
May 27th	Rakesh Misra Vmware (Uhana)			rmisra@vmware.com

June

Date	Speaker	Title/Topic		Address
June 3rd	Jason Martin Intel (and Georgia Tech)	“Guaranteeing Artificial Intelligence (AI) Robustness against Deception (GARD)”	DARPA Program	jason.martin@intel.com
June 10th	Berge Ayvazian Wireless 20 20		Analyst View of AI/ML for Telecomms	berge@wireless2020.com
June 17th	Tan F. Wong John M. Shea University of Florida		DARPA Spectrum Challenge	twong@ece.ufl.edu jshea@ece.ufl.edu
June 24th	Peter Volgyesi, Miklos Maroti, Peter Horvath, Sandor Szilvasi Vanderbilt University		DARPA Spectrum Challenge	peter.volgyesi@vanderbilt.edu mmaroti@gmail.com ejcspii@gmail.com sandor.szilvasi@gmail.com

July

Date	Speaker	Title/Topic		Address
July 1st	Harry Surden University of Colorado Law School	“Machine Learning and Law”	Gain understanding of data rights, ethical use, other FCC-relevant legal considerations. Safe Use of AI	hsurden@Colorado.edu
July 8th	Martin Zoltick Jennifer Maisel Rothwell Figg		Legal aspects of AI/ML, Safe use of AI	Mzoltick@rothwellfigg.com jmaisel@rothwellfigg.com
July 15th	Ramana Jampala Avlino	“Predictive Modeling & Machine learning-based optimization of network operations”	AI use case for network operations. Illustrations of what is in place and working	ramana.jampala@avlino.com
July 22nd	Keith Gremban University of Colorado	Existing Federal Initiatives for AI and Spectrum Sharing	Spectrum Sharing and use of AI to improve FCC models	kdgremban@gmail.com
July 29th	Jeff Alstott , IARPA Alexander Sprintson , NSF	“Security of AI Systems” “Impacts of AI in the Wireless Networking domain”	Secure use of AI. MLWiNS – NSF Intel Partnership.	jeff.alstott@iarpa.gov asprints@nsf.gov

August

Date	Speaker	Title/Topic		Address
August 5th	Elham Tabassi			elham.tabassi@nist.gov gerlinde.harr@nist.gov
August 12th	Rafail Ostrovsky			rafail@stealthsoftwareinc.com
August 19th				
August 26th				

Appendix 2. Speaker Biographies



Ulrika Jägare

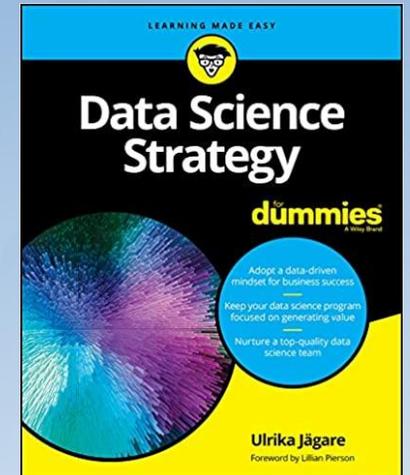


Head of AI/ML Strategy
Execution at Ericsson



“How AI is Shaping Telecom Operations”

- **Ulrika Jägare** is an M.Sc. Director at Ericsson AB. With a decade of experience in analytics and machine intelligence and 19 years in telecommunications, she has held leadership positions in R&D and product management. Ulrika was key to the Ericsson’s Machine Intelligence strategy and the recent Ericsson Operations Engine launch – a new data and AI driven operational model for Network Operations in telecommunications. She is the Head of AI/ML Strategy Execution at Ericsson.



Mazin E. Gilbert

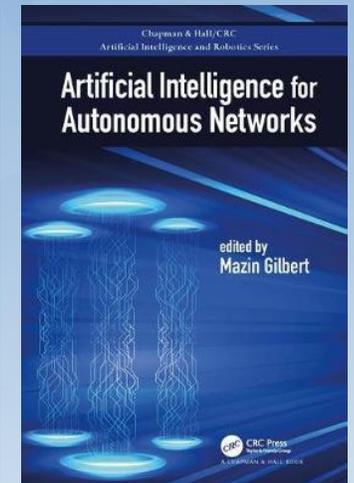


Vice President of Technology
and Innovation AT&T Research



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- **Mazin E. Gilbert**, Ph.D., MBA leads AT&T's research and advanced development for a software-defined network, overseeing advancements in networking and IP network management, network virtualization, big data, speech and multimedia technologies, information systems and visualization, algorithms and optimization, and scalable, reliable software systems. His business areas of focus include product strategy and development, entrepreneurship, and corporate finance. He is the recipient of the AT&T Science and Technology Medal Award (2006).



Mukarram Bin Tariq Nandita Dukkipati



Software Engineers at Google Inc.



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- **Nandita Dukkipati** is a Principal Engineer, leading Congestion Control and end-to-end Telemetry systems at Google. Her mission at Google is to deliver excellent end-to-end network performance for applications through making better use of shared capacity, smarter scheduling systems / QOS, providing end-to-end visibility into application behavior and making network control schemes work well at scale. She has published ward-winning papers in premier Networking conferences with fundamental contributions to Congestion Control, traffic shaping, and Bandwidth Management. She received her PhD from Stanford University in Electrical Engineering in 2008.
- **Muhammad Mukarram Bin Tariq** leads the network systems management area at Google. His team is responsible for the systems that make critical network changes to meet the ever-increasing network and compute capacity needs for Google and its customers. This is enabled through high velocity in operations while simultaneously maintaining the highest standards of availability and safety. In his ten years at Google, Mukarram has made numerous contributions to Google's cluster and edge networking, enabling new capabilities, high performance for our users, and allowing Google to scale. Some of these contributions are published, e.g., the Espresso work in Sigcomm 2015. Mukarram received his PhD in Computer Science from Georgia Tech in 2010.



Rakesh Misra



Co-Founder Uhana (now part of VMware)

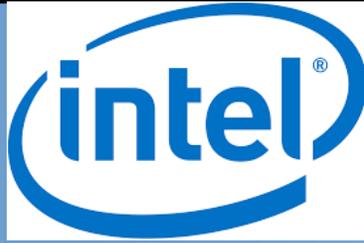


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- **Rakesh Misra** is Co-founder Uhana Inc (now part of VMWare). He received his PhD from Stanford University, and B.Tech & M.Tech from IIT Madras. He was born/and grew up in Bhubaneswar/Berhampur, Odisha.



Jason Martin



Principal Engineer, Intel



“Improving cyber-defenses against deception attacks on machine learning models” **DARPA GARD Program**

- **Jason Martin** is a Senior Staff Research Scientist in the Security Solutions Lab and manager of the Secure Intelligence Team at Intel Labs. He leads a team of diverse researchers to investigate machine learning security in a way that incorporates the latest research findings and Intel products. Jason’s interests include machine learning, authentication and identity, trusted execution technology, wearable computing, mobile security, and privacy. Prior to Intel labs he spent several years as a security researcher performing security evaluations and penetration tests on Intel’s products. Jason is a co-inventor on 19 patents and received his BS in Computer Science from the University of Illinois at Urbana-Champaign.



Berge Ayvazian



**Senior Analyst/Consultant at
Wireless 20|20**



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- **Berge Ayvazian** Berge Ayvazian is a senior telecom industry analyst and consultant, with a 30-year career including more than 20 years with Yankee Group where he served as CEO. As a Senior Analyst and Consultant with Wireless 20/20, he leads an integrated practice to help operators secure 5G spectrum and work with vendors to develop their wireless technology roadmaps and build a complete WiROI™ Business Case.
- Ayvazian is currently conducting research on Wireless Networks, IoT and AI Strategies, and how the wireless industry can harness AI and machine learning in the climb to 5G networks. Ayvazian has also served a frequent speaker and program director for mobile and telecom industry events worldwide, including Big 5G, AI World, 5G North America, Tower & Small Cell Summit and 4G World and Mobile Internet World conferences. The following are some articles written last year for [AI Trends](#).
- [5G Wireless Networks And AI Will Power Enterprise Digital Transformation](#)
- [Employing AI to Enhance Returns on 5G Network Investments](#)
- [AI at the 5G Wireless Network Edge](#)
- [Mobile Visions: IBM's Plans for AI, Cloud Computing, 5G Networks](#)
- [What is the Potential ROI from AI in 5G Wireless Networks?](#)



Tan F. Wong
John M. Shea



GatorWings Team – DARPA Spectrum Challenge



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- **Tan F. Wong** is a Professor of electrical and computer engineering at the University of Florida. His research activities mainly aim towards achieving intelligent and secure use of the radio spectrum. Tan recently led Team GatorWings, a team of students and professors, to win the DARPA Spectrum Collaboration Challenge, in which competing teams employed AI technologies to share the radio spectrum with each other and incumbent networks autonomously and efficiently.
- **John M. Shea** is a Professor of electrical and computer engineering at the University of Florida. His research is in the areas of wireless communications and networking, with emphasis on military communications, software-defined radio, networked autonomous systems, and security and privacy in communications. He was co-leader of Team GatorWings, the overall winner of the DARPA Spectrum Collaboration Challenge.

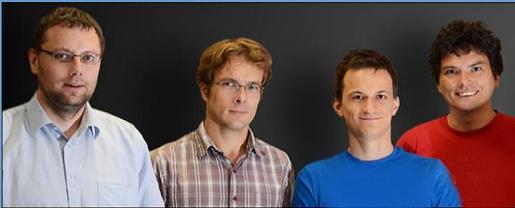


**Peter Volgyesi, Miklos Maroti,
Peter Horvath, Sandor Szilvasi**



VANDERBILT
UNIVERSITY

**MarmotE Team DARPA
Spectrum Challenge**



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- **Péter Völgyesi** is a Research Scientist at the Institute for Software Integrated Systems, Vanderbilt University. His current research interests include wireless sensor networks and domain specific modeling environments. He received an M.Sc. in Computer Science from the Budapest University of Technology and Economics.
- **Miklos Maroti** a former EECS research associate professor, is an associate professor at the University of Szeged, Hungary.
- **Peter Horvath** a former postdoctoral scholar at ISIS, is an associate professor at Budapest University of Technology.
- **Sandor Szilvasi** PhD'14 and former ISIS research assistant, is a radio frequency and FPGA (field-programmable gate array) engineer in Atlanta.



Harry Surden



University of Colorado
Boulder

Associate Professor, University
of Colorado at Boulder



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- **Harry Surden** Harry Surden is an Associate Professor of Law at the University of Colorado Law School. He joined the faculty in 2008. His scholarship focuses upon legal informatics, artificial intelligence and law (including machine learning and law), legal automation, and issues concerning self-driving/autonomous vehicles. He also studies intellectual property law with a substantive focus on patents and copyright, and information privacy law. Prior to joining CU, Professor Surden was a resident fellow at the [Stanford Center for Legal Informatics \(CodeX\) at Stanford Law School](#). In that capacity, Professor Surden conducted interdisciplinary research with collaborators from the Stanford School of Engineering exploring the application of computer technology towards improving the legal system. He was also a member of the Stanford Intellectual Property Litigation Clearinghouse and the director of the Computer Science and Law Initiative. Professor Surden was law clerk to the Honorable Martin J. Jenkins of the United States District Court for the Northern District of California in San Francisco. He received his law degree from Stanford Law School with honors and was the recipient of the Stanford Law Intellectual Property Writing Award. Prior to law school, Professor Surden worked as a software engineer for Cisco Systems and Bloomberg L.P. He received his undergraduate degree with honors from Cornell University.



Martin Zoltick Jennifer Maisel



ROTHWELL FIGG
IP Professionals



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- **Martin M. Zoltick** is a technology lawyer with more than 30 years of experience representing inventors, innovators, entrepreneurs, and investors. Marty has a degree in computer science and, prior to attending law school, he worked for several years as a software developer and engineer. His formal training in computer science and technical experience as a practicing software developer and engineer has enabled him to handle complex software-related legal matters successfully in a cost-effective and efficient manner. Marty's practice is focused primarily on intellectual property (IP) matters, transactions, and privacy, data protection, and cybersecurity. He is a registered patent attorney, and a substantial part of his practice involves drafting and prosecuting patent applications and, along with that, developing with his clients IP strategic plans designed to maximize value and satisfy both legal and business objectives. Marty also has significant experience handling contested cases and disputes on behalf of his clients. He regularly serves as trial counsel in major patent disputes in the U.S. federal district courts and as lead counsel in post-grant proceedings before the U.S. Patent and Trademark Office Patent Trial and Appeal Board.
- **Jennifer Maisel** An emerging thought leader on the intersection of artificial intelligence and the law, Jen makes use of her technical background in information science and operations research in her practice focusing on intellectual property and privacy law issues involving cutting edge technology. Her practice encompasses all aspects of intellectual property law including litigation, patent prosecution, transactions, opinions, and counselling. She is also a Certified Information Privacy Professional in the United States (CIPP/US) and counsels clients on privacy and data security matters. She has been selected to the Washington, DC Super Lawyers "Rising Star" list in 2018, 2019, and 2020. Jen joined the firm full time in 2012 after graduating with honors from The George Washington University Law School. She also graduated *cum laude* from Cornell University's College of Engineering with a B.S. degree in Information Science, Systems, and Technology with a specialization in Operations Research and Information Engineering. She is registered to practice before the United States Patent and Trademark Office.



Ramana Jampala



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- In the past 2 decades **Ramana Jampala** has founded, led investments, or was a Board of Director of numerous technology companies in Silicon Valley and New York/New Jersey in the United States. Ramana is currently the founding President and CEO of Avlino Inc – an AI and Data Analytics company. Prior to Avlino, Ramana was the President and CEO of Altior Inc – a Big Bata pioneering company, which was acquired by Exar (NYSE: EXAR). Earlier Ramana was a General Partner with SAS Investors, a Venture Capital fund in New York City. Ramana has invested in or served as the Board of Director on many of SAS portfolio investments including Tacit Networks (acquired by Packateer), Velox Semiconductors (acquired by Power Semiconductors), HydroGlobe (acquired by Graver Technologies), Textronics (acquired by Adidas), Protonex (public company) and Enpirion (acquired by Altera). Prior to SAS Investors, Ramana worked with Viant (NASDAQ: VIAN) as a Strategy Lead in San Francisco. He had his initial career with Rockwell Automation (Allen-Bradley) in the Control and Communications Group. Well recognized for his accomplishments, Ramana was awarded the “Financier of the Year” by New Jersey Technology Council, for leading more than \$250M Investments in early stage companies in New Jersey. Ramana frequently teaches Technology Entrepreneurship at leading Business Schools in the United States, and is a Board of Advisors of numerous academic institutions. Ramana holds an MBA from London Business School, and graduated with distinction with a BS in Electronics Engineering from Pune University, India.



Keith Gremban



University of Colorado
Boulder

Research Professor University of
Colorado at Boulder



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- **Keith Gremban** is a Research Professor in the Technology, Cybersecurity, and Policy (TCP) Program at the University of Colorado Boulder. Keith has been involved in systems engineering and advanced technology development for over thirty years.
- Prior to joining the University of Colorado, Keith was the Director of the Institute for Telecommunication Sciences (ITS), which is the research and engineering laboratory for the National Telecommunications and Information Administration (NTIA). Keith was also a Program Manager at the Defense Advanced Research Projects Agency (DARPA) where he managed a portfolio of programs in the areas of wireless communications and electronic warfare. Prior to DARPA, Keith worked at a variety of companies and research organizations, managing and leading research and systems engineering projects, including a diverse collection of unmanned systems and command-and-control applications.
- Keith received his Ph.D. and M.S. in Computer Science from Carnegie Mellon University, and his M.S. in Applied Mathematics and B.S. in Mathematics from Michigan State University.



Jeff Alstott Alexander Sprintson



Program Directors IARPA and NSF



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- **Dr. Jeff Alstott** is a program manager at IARPA (the Intelligence Advanced Research Projects Activity). He previously worked for MIT, Singapore University of Technology and Design, the World Bank and the University of Chicago. He obtained his PhD studying complex networks at the University of Cambridge, and his MBA and bachelor's degrees from Indiana University. He has published research in such areas as animal behavior, computational neuroscience, complex networks, design science, statistical methods, and S&T forecasting.
- **Alexander Sprintson** is a faculty member in the Department of Electrical and Computer Engineering, at Texas A&M University, College Station, where he conducts research on wireless networks, distributed storage, and software-defined networking. Dr. Sprintson received the Wolf Award for Distinguished Ph.D. students, the Viterbi Postdoctoral Fellowship, the TAMU College of Engineering Outstanding Contribution award, and the NSF CAREER award. From 2013 and 2019 he served as an Associate Editor of the IEEE Transactions on Wireless Communications. He has been a member of the Technical Program Committee for the IEEE Infocom 2006--2020. He joined NSF in September 2018 where he currently serves as a Program Director in the Directorate of Computer & Information Science and Engineering (CISE). He manages networking research within the Networking Technologies and Systems (NeTS) and Secure and Trustworthy Cyberspace (SaTC) programs.



Elham Tabassi



Chief of Staff in the Information Technology Laboratory (ITL) at NIST



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- **Elham Tabassi** is the acting Chief of Staff in the Information Technology Laboratory (ITL) at the National Institute of Standards and Technology (NIST). ITL, one of six research Laboratories within NIST, supports NIST’s mission, to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. ITL conducts fundamental and applied research in computer science and engineering, mathematics, and statistics that cultivates trust in information technology and metrology by developing and disseminating standards, measurements, and testing for interoperability, security, usability, and reliability of information systems.
- As a scientist she has been working on various computer vision research projects with applications in biometrics evaluation and standards since 1999. She is the principal architect of NIST Fingerprint Image Quality (NFIQ) which is now an international standard for measuring fingerprint image quality and has been deployed in many large-scale biometric applications worldwide. She received the Department of Commerce Gold Medal in 2003, the Department of Commerce Bronze Medal in 2007, and 2010, ANSI’s 2012 Next Generation Award, and the Women in Biometrics Award in 2016 for her contributions to biometrics. She is a member of OSAC Friction Ridge subcommittee and co-chairs FIDO Biometrics Certification working group.



Rafail Ostrovsky



Distinguished Professor at UCLA
And Founder
Stealth Software Technologies



“ Preservation of Privacy in Data and Computing”

- **Rafail Ostrovsky** is a Distinguished Professor of Computer Science and Distinguished Professor of Mathematics at UCLA. Prof. Ostrovsky joined UCLA in 2003 as a full tenured professor, coming from Bell Communications Research where he was a Senior Research Scientist. Prior to beginning his career at Bellcore, he was an NSF Mathematical Sciences Postdoctoral Research Fellow at UC Berkeley. Dr. Ostrovsky received his Ph.D. in computer science from [MIT](#) in 1992, (advisor: Silvio Micali, thesis: [Software Protection and Simulation on Oblivious RAM](#)), supported by IBM Graduate Fellowship. Prof. Ostrovsky is a Fellow of IEEE; Fellow of IACR; and a foreign member of Academia Europaea. He has 14 U.S. patents issued and over 300 papers published in refereed journals and conferences. Dr. Ostrovsky has served as a Chair of the IEEE Technical Committee on Mathematical Foundations of Computing from 2015-2018 and has served on over 40 international conference Program Committees including serving as PC chair of FOCS 2011. He is a member of the Editorial Board of [Journal of ACM](#); Editorial Board of [Algorithmica](#); and the Editorial Board of [Journal of Cryptology](#) and is the recipient of multiple awards and honors including the 2017 IEEE Computer Society Technical Achievement Award and the 2018 RSA Conference *Excellence in the Field of Mathematics* lifetime achievement Award. At UCLA, Prof. Ostrovsky heads the Center of Information and Computation Security (CICS) a multi-disciplinary [Research Center](#) (<http://www.cs.ucla.edu/security/>) at Henry Samueli School of Engineering and Applied Science.



Eric Horvitz



Fellow and CTO Microsoft



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- **Eric Horvitz** is a technical fellow at Microsoft, where he serves as the company's first Chief Scientific Officer. As chief scientist of the company, Dr. Horvitz provides cross-company leadership and perspectives on advances and trends on scientific matters, and on issues and opportunities rising at the intersection of technology, people, and society. He has pursued principles and applications of AI with contributions in machine learning, perception, natural language understanding, and decision making. His research centers on challenges with uses of AI amidst the complexities of the open world, including uses of probabilistic and decision-theoretic representations for reasoning and action, models of bounded rationality, and human-AI complementarity and coordination.
- His efforts and collaborations have led to fielded systems in healthcare, transportation, ecommerce, operating systems, and aerospace. He received the Feigenbaum Prize and the Allen Newell Prize for contributions to AI. He received the CHI Academy honor for his work at the intersection of AI and human-computer interaction. He has been elected fellow of the National Academy of Engineering (NAE), the Association of Computing Machinery (ACM), Association for the Advancement of AI (AAAI), the American Association for the Advancement of Science (AAAS), the American Academy of Arts and Sciences, and the American Philosophical Society. He has served as president of the AAAI, and on advisory committees for the National Science Foundation, National Institutes of Health, President's Council of Advisors on Science and Technology, DARPA, and the Allen Institute for AI.
- Beyond technical work, he has pursued efforts and studies on the influences of AI on people and society, including issues around ethics, law, and safety. He chairs Microsoft's Aether committee on AI, effects, and ethics in engineering and research. He established the *One Hundred Year Study* on AI at Stanford University and co-founded the Partnership on AI.
- Eric received PhD and MD degrees at Stanford University. Previously, he served as director of Microsoft Research Labs, including research centers in Redmond, Washington, Cambridge, Massachusetts, New York, New York, Montreal, Canada, Cambridge, UK, and Bangalore, India. He also ran the Microsoft Research Lab in Redmond, Washington.



Thank You!



Closing Remarks

Adjourned

